MAKING MODERN LIVING POSSIBLE

SOLAR INVERTERS

# Design Guide
# FLX Series

www.danfoss.com/solar

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# 1 Introduction

The Design Guide provides information required for planning an installation. It describes requirements for use of the FLX series inverters in solar energy applications.

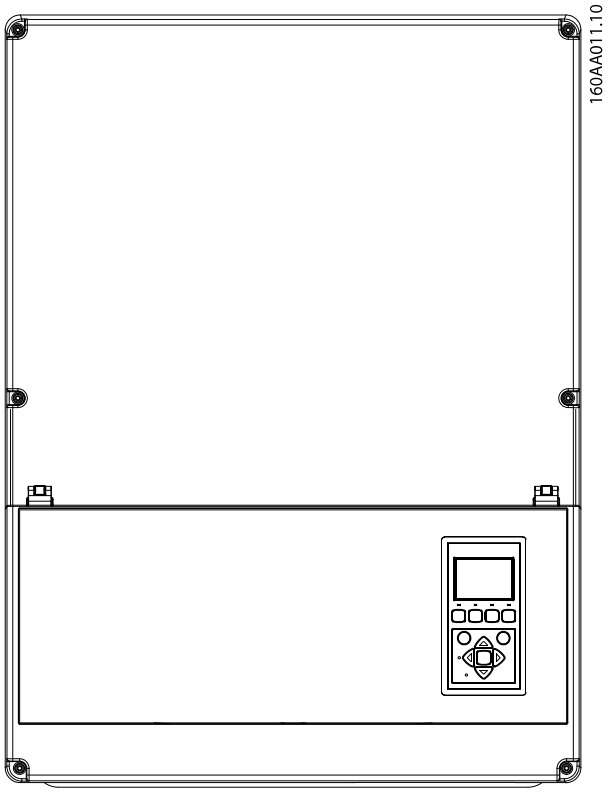



**Illustration 1.1 FLX Series Inverter**

**Additional resources available**

- *Installation Guide*, supplied with the inverter, for information required to install and commission the inverter.
- *User Guide*, for information required for monitoring and setup of the inverter, via the display or web interface.
- *CLX GM Manual*, for information required to install and set up power management of the FLX Pro inverter.
- *CLX Home GM Installation Manual*, or *CLX Standard GM Installation Manual* for information required to install and set up monitoring of the FLX series inverter.
- *Sensor Interface Option Installation Guide*, for installation and commissioning of temperature and irradiation monitoring sensors, and using energy meter input (S0) and relay output.
- *GSM Option Kit Installation Guide*, for information required to install a GSM board, and set up data upload or messaging from the inverter.
- *PLA Option Guide*, for information required to install and set up PLA option for connecting radio ripple control receiver to the inverter.
- *Fan Installation Instruction*, for information required to replace a fan.

These documents are available from the download area at *www.danfoss.com/solar*, or from the supplier of the solar inverter. Additional application-specific information is available at the same location.

| Chapter | Content |
|---|---|
| 2, 5 | Functionality and specifications of the inverter |
| 3 | System design, pre-installation and planning considerations |
| 4 | Options |

**Table 1.1 Content Overview**

Functional safety and grid management parameters are password-protected.

## 1.1 List of Symbols

| Symbol | Explanatory note |
|---|---|
| *Italics* | 1) Indicates reference to a section of the present manual.<br>2) *Italics* are also used to indicate an operation mode, e.g. operation mode *Connecting*. |
| [ ] used in text | 1) Encloses a path of menu navigation.<br>2) Also used to enclose abbreviations such as [kW]. |
| [x] superscripted in headlines | Indicates security level. |
| [Plant] | Menu item accessible at plant level. |
| [Group] | Menu item accessible at group level or above. |
| [Inverter] | Menu item accessible at inverter level or above. |
| → | Indicates a step within menu navigation. |
| | Note, useful information. |
| | Caution, important safety information. |
| # ... # | Name of plant, group or inverter in e-mail message, eg. #plant name#. |
| **Site Map** | |
| **Symbol** | **Explanatory note** |
| ↳ | Indicates a submenu. |
| [x] | Defines current security level, where x is between 0-3. |

**Table 1.2 Symbols**

1

## 1.2 List of Abbreviations

| Abbreviation | Description |
|---|---|
| cat5e | Category 5 twisted pair cable (enhanced) |
| DHCP | Dynamic Host Configuration Protocol |
| DNO | Distribution Network Operator |
| DSL | Digital Subscriber Line |
| EMC (Directive) | Electromagnetic Compatibility Directive |
| ESD | Electrostatic Discharge |
| FRT | Fault ride through |
| GSM | Global System for Mobile communications |
| IEC | International Electrotechnical Commission |
| LED | Light-emitting diode |
| LVD (Directive) | Low Voltage Directive |
| MPP | Maximum power point |
| MPPT | Maximum power point tracking |
| P | P is the symbol for active power and is measured in Watts (W) |
| PCB | Printed Circuit Board |
| PCC | Point of common coupling<br>The point on the public electricity network to which other customers are, or could be, connected. |
| PE | Protective Earth |
| PELV | Protected extra-low voltage |
| PLA | Power Level Adjustment |
| $P_{NOM}$ | Power, Nominal conditions |
| POC | Point of connection<br>The point at which the PV system is connected to the public electricity grid. |
| $P_{STC}$ | Power, Standard Test Conditions |
| PV | Photovoltaic, photovoltaic cells |
| RCMU | Residual Current Monitoring Unit |
| $R_{ISO}$ | Insulation Resistance |
| ROCOF | Rate Of Change Of Frequency |
| Q | Q is the symbol for reactive power and is measured in reactive volt-amperes (VAr) |
| S | S is the symbol for apparent power and is measured in volt-amperes (VA) |
| STC | Standard test conditions |
| SW | Software |
| THD | Total Harmonic Distortion |
| TN-S | Terra Neutral - Separate. AC Network |
| TN-C | Terra Neutral - Combined. AC Network |
| TN-C-S | Terra Neutral - Combined - Separate. AC Network |
| TT | Terra Terra. AC Network |

**Table 1.3 Abbreviations**

## 1.3 Software Version

This manual is applicable for inverter software 2.05 and onwards. To see the software version, via the display or web interface (inverter level), go to [Status → Inverter → Serial no. and SW ver. → Inverter].

***NOTICE***

**Software version at manual release is 2.05. Information about current software version is available at *www.danfoss.com/solar*.**

# 2 Inverter Overview



## 2.1 FLX Series Inverter Features

- IP65 enclosure
- PV load switch
- Sunclix connectors for PV input
- Access via the display, for configuration and monitoring of the inverter
- Ancillary service functionalities. Refer to *2.6 Ancillary Services* for details.
- Access via web interface, for configuration and monitoring of the inverter.

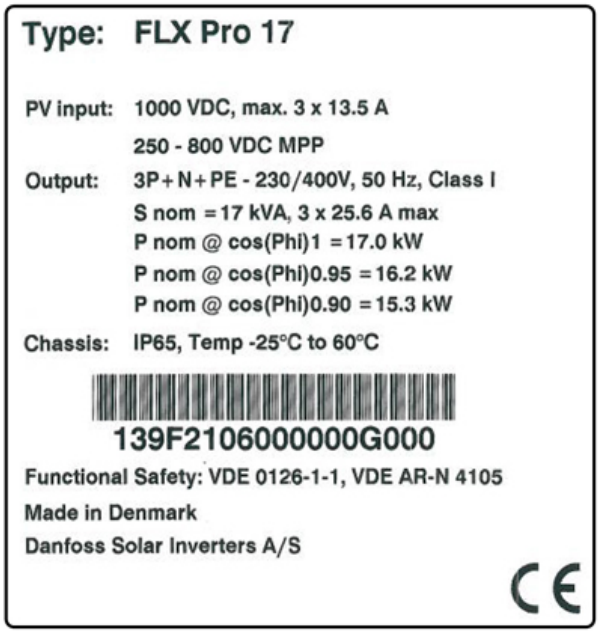

Type: FLX Pro 17
PV input: 1000 VDC, max. 3 x 13.5 A
250 - 800 VDC MPP
Output: 3P+N+PE - 230/400V, 50 Hz, Class I
S nom = 17 kVA, 3 x 25.6 A max
P nom @ cos(Phi)1 = 17.0 kW
P nom @ cos(Phi)0.95 = 16.2 kW
P nom @ cos(Phi)0.90 = 15.3 kW
Chassis: IP65, Temp -25°C to 60°C
139F2106000000G000
Functional Safety: VDE 0126-1-1, VDE AR-N 4105
Made in Denmark
Danfoss Solar Inverters A/S

**Illustration 2.1 Product Label**

The product label on the side of the inverter shows:

- Inverter type
- Important specifications
- Serial number, located under the bar code, for inverter identification.

## 2.2 Mechanical Overview of the Inverter

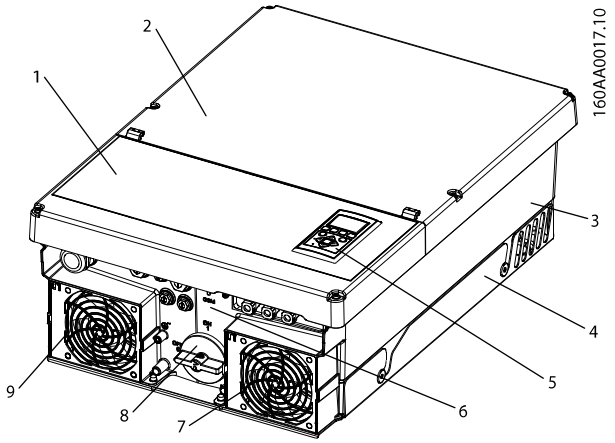



**Illustration 2.2 Mechanical Overview of the Inverter**

| | |
|---|---|
| 1 | Cover for installation area |
| 2 | Front cover |
| 3 | Die-cast aluminium heat sink |
| 4 | Mounting plate |
| 5 | Display |
| 6 | GSM antenna (optional) mounting position |
| 7 | Fan |
| 8 | PV load switch |
| 9 | Fan |

## 2.3 Description of the Inverter

### 2.3.1 Functional Overview

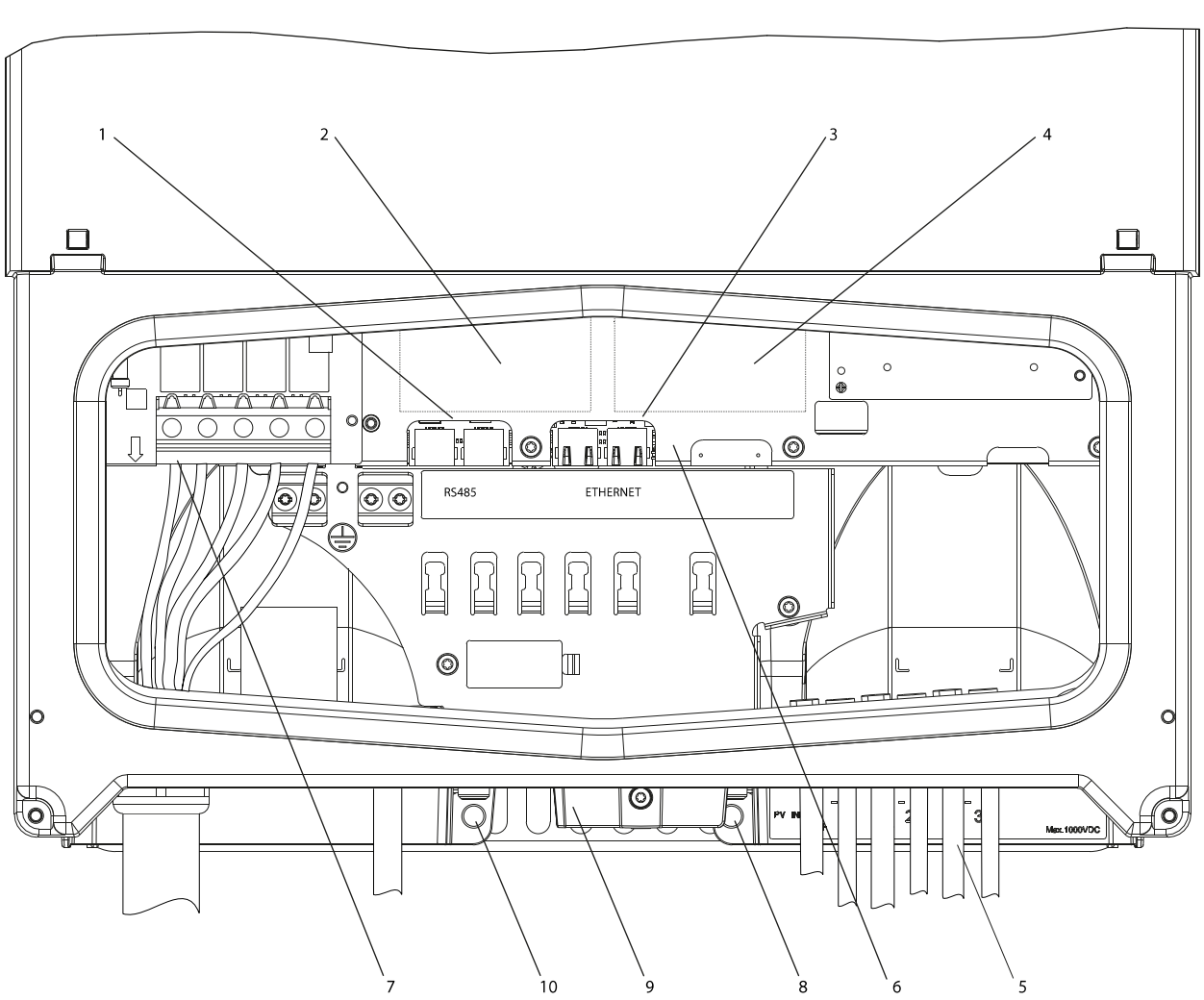
Advantages of the FLX series inverter:

- Transformerless
- 3-phase
- 3-level inverter bridge with a high performance
- 2 or 3 separate PV inputs for maximum flexibility
  - Equivalent number of MPP trackers
- Integrated residual current monitoring unit
- Insulation test functionality
- Integrated PV load switch
- Extended fault ride through capabilities (to support reliable power generation during grid faults)
- Compliant with a wide range of international grids

- Adapted to local requirements and conditions via grid code setting

The inverter has several interfaces:

- User interface
  - Display
  - Web interface
  - Service web interface
- Communication interface
  - RS-485
  - Ethernet
- Sensor interface option
  - Energy meter input
  - Irradiation sensor input
  - Temperature sensor inputs: 3 x PT1000
  - Relay output for triggering alarm or self-consumption
- GSM option
  - Antenna input
  - SIM card input
- PLA option
  - 6 digital inputs, e.g. for connecting ripple control receiver, for controlling active and reactive power




| | |
|---|---|
| **PELV (Safe to touch)** | |
| 1 | RS-485 interface |
| 2 | Option slot A (can be used for GSM option, optional sensor interface, or PLA option) |
| 3 | Ethernet interface |
| 4 | Option slot A (can be used for GSM option, optional sensor interface, or PLA option) |
| **Live Part** | |
| 5 | PV connection area |
| 6 | Communication board |
| 7 | AC terminal |
| **Other** | |
| 8 | Security screw position |
| 9 | PV load switch |
| 10 | Security screw position |

**Illustration 2.3 Overview of Installation Area**

## 2.3.2 Functional Safety

The inverter is designed for international use, with functional safety circuit design meeting a wide range of international requirements (see *2.3.4 International Inverter*).

**Single-fault Immunity**

The functional safety circuit is designed with 2 independent monitoring units, each having control of a set of grid-separation relays to guarantee single-fault

immunity. All functional safety circuits are tested during start-up to ensure safe operation. If a circuit fails more than 1 out of 3 times during the self-test, the inverter enters fail safe mode. If the measured grid voltages, grid frequencies, or residual current during normal operation differ too much between the 2 independent circuits, the inverter ceases to energise the grid and repeats the self-test. The functional safety circuits are always activated and cannot be disabled.

**Grid Surveillance**
Grid-related matters are under constant surveillance when the inverter energises the grid. The following parameters are monitored:

- Grid voltage magnitude (instantaneous and 10-minute average).
- Grid voltage and frequency.
- 3-phase Loss-of-Mains (LoM) detection.
- Rate-of-Change-of-Frequency (ROCOF).
- DC content of grid current.
- Residual Current Monitoring Unit (RCMU).
- Active frequency shift.

The inverter ceases to energise the grid if 1 of the parameters violates the grid code.

**Self-test**
The insulation resistance between the PV arrays and earth is also tested during the self-test. The inverter will not energise the grid if the resistance is too low. It will then wait 10 minutes before making a new attempt to energise the grid.

## 2.3.3 Operation Modes

The inverter has 4 operation modes, indicated by LEDs.

**Off grid** (LEDs off)
When no power has been delivered to the AC grid for more than 10 minutes, the inverter disconnects from the grid and shuts down. 'Off grid - standby' is the default night mode.

- **Off grid - standby mode** (LEDs off)
  The inverter is disconnected from grid. User and communication interfaces remain powered for communication purposes.

**Connecting** (Green LED flashing)
The inverter starts up when the PV input voltage reaches 250 V. The inverter performs a series of internal self-tests, including PV autodetection and measurement of the resistance between the PV arrays and earth. Meanwhile, it also monitors the grid parameters. When the grid parameters have been within the specifications for the required amount of time (depends on grid code), the inverter starts to energise the grid.

**On grid** (Green LED on)
The inverter is connected to the grid and energises the grid. The inverter disconnects when:

- it detects abnormal grid conditions (dependent on grid code), or
- an internal event occurs, or
- insufficient PV power is available (no power is supplied to the grid for 10 minutes).

The inverter then enters connecting mode or off grid mode.

**Fail Safe** (Red LED flashing)
If the inverter detects an error in its circuits during the self-test (in connecting mode) or during operation, the inverter goes into fail safe mode, disconnecting from grid. The inverter will remain in fail safe mode until power has been absent for a minimum of 10 minutes, or the inverter has been shut down completely (AC+PV).

## 2.3.4 International Inverter

The inverter is equipped with a range of grid codes to meet national requirements.
Before connecting an inverter to the grid, obtain approval from the local distribution network operator (DNO).
For initial selection of grid code, refer to the *FLX Installation Guide*.

**Grid power quality enhancement settings**
For further information, see *2.6 Ancillary Services*.

**Functional safety settings**

- The cycle RMS values of the grid voltages are compared with 2 lower and 2 upper trip settings, e.g. overvoltage (stage 1). If the RMS values violate the trip settings for more than the duration of "clearance time", the inverter ceases to energise the grid.
- Loss of Mains (LoM) is detected by 2 different algorithms:
  1. 3-phase voltage surveillance (the inverter has individual control of the 3-phase currents). The cycle RMS values of the phase-phase grid voltages are compared with a lower trip setting or an upper trip setting. If the RMS values

violate the trip settings for more than the duration of "clearance time", the inverters cease to energise the grid.

2. Rate of change of frequency (ROCOF). The ROCOF values (positive or negative) are compared to the trip settings and the inverter ceases to energise the grid when the limits are violated.

- Residual current is monitored. The inverter ceases to energise the grid when:
  - the cycle RMS value of the residual current violates the trip settings for more than the duration of "clearance time", or
  - a sudden jump in the DC value of the residual current is detected.
- Earth-to-PV isolation resistance is monitored during start-up of the inverter. If the value is too low, the inverter will wait 10 minutes and then make a new attempt to energise the grid. **Note**: Depending on the local legislation, a minimum earth-to-PV isolation resistance is defined. The defined value is offset by 20% in the range of 100 kΩ - 1 MΩ, and by 40% in the range of 20 kΩ - 100 kΩ in order to allow for measuring inaccuracy. For example, a 200 kΩ limit will have an offset of 40 kΩ and therefore the applied limit will be 240 kΩ.

If the inverter ceases to energise the grid due to grid frequency or grid voltage (not 3-phase LoM), and if the frequency or voltage is restored within a short time (short-interruption time), the inverter can reconnect when the grid parameters have been within their limits for the specified time (reconnect time). Otherwise, the inverter returns to the normal connection sequence.

## 2.3.5 Derating

Derating the output power is a means of protecting the inverter against overload and potential failure. Furthermore, derating can also be activated to support the grid by reducing or limiting the output power of the inverter. Derating is activated by:

1. PV overcurrent
2. Internal overtemperature
3. Too low grid voltage
4. Grid over-frequency[1)]
5. External command (PLA feature)[1)]

[1)] See *2.6 Ancillary Services.*

Derating is accomplished by adjusting the PV voltage and subsequently operating outside the maximum power point of the PV arrays. The inverter continues to reduce the power until the potential overload ceases or the PLA level is reached. Derating due to excessive temperature in the inverter is caused by PV over-sizing, whereas derating due to grid current, grid voltage and grid frequency indicates issues with the grid.
See *2.6 Ancillary Services* for more information.

During temperature derating, the output power may fluctuate.

**1. PV Overcurrent**
For the inverter the maximum MPPT PV current is 12 A. When a PV current of 12.3 A is reached the inverter will start to derate the input power. Above 13 A the inverter will trip.

**2. Internal Overtemperature**
Derating due to temperature is a sign of excessive ambient temperature, a dirty heat sink, a blocked fan or similar. Refer to the *FLX Installation Guide* regarding maintenance. The values shown in the graphs below are measured at nominal conditions cos(φ) = 1.

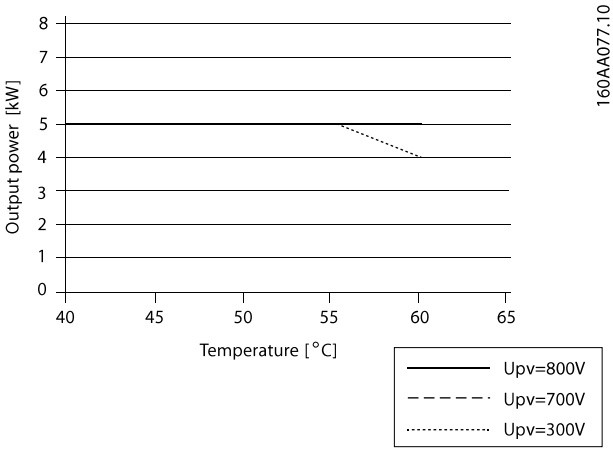



**Illustration 2.4 Derating Temperature, FLX 5**

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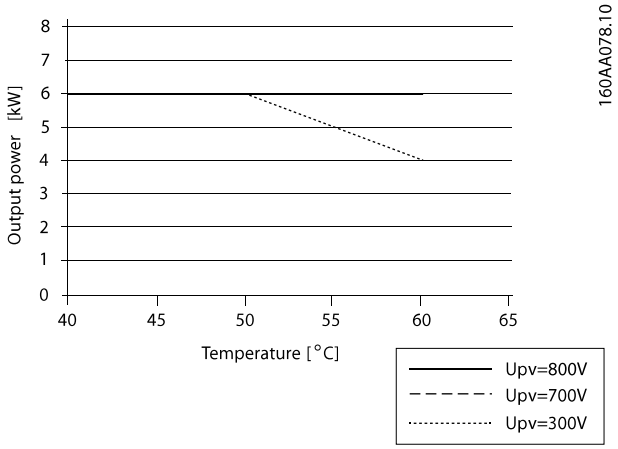



**Illustration 2.5 Derating Temperature, FLX 6**

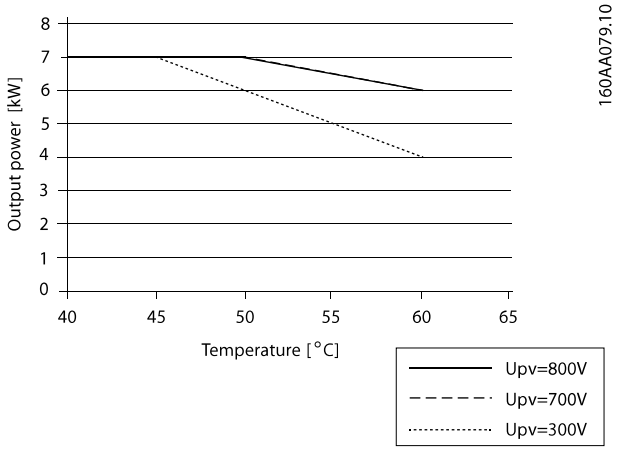



**Illustration 2.6 Derating Temperature, FLX 7**

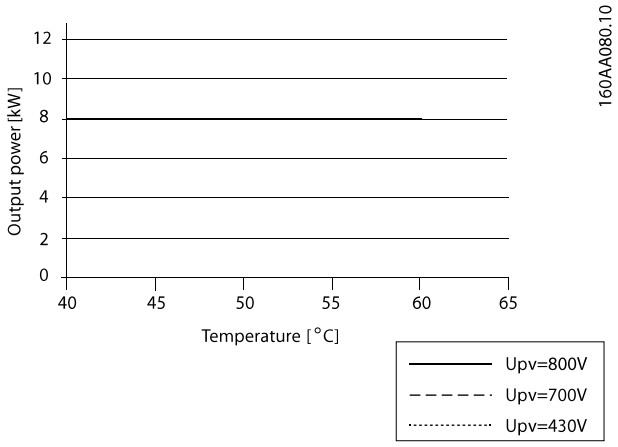



**Illustration 2.7 Derating Temperature, FLX 8**

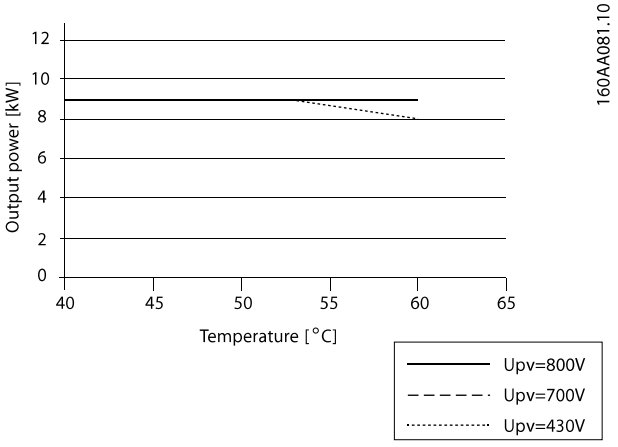



**Illustration 2.8 Derating Temperature, FLX 9**

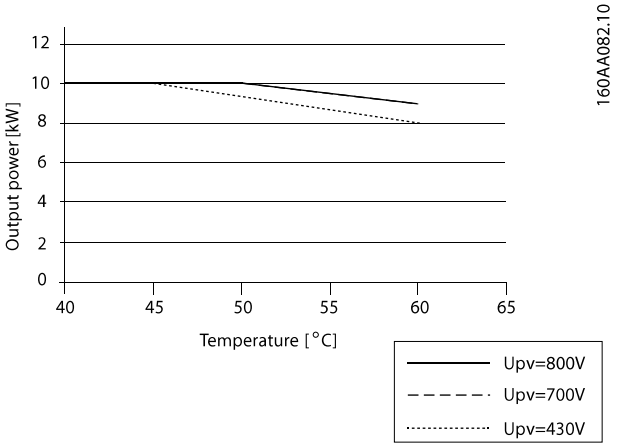



**Illustration 2.9 Derating Temperature, FLX 10**

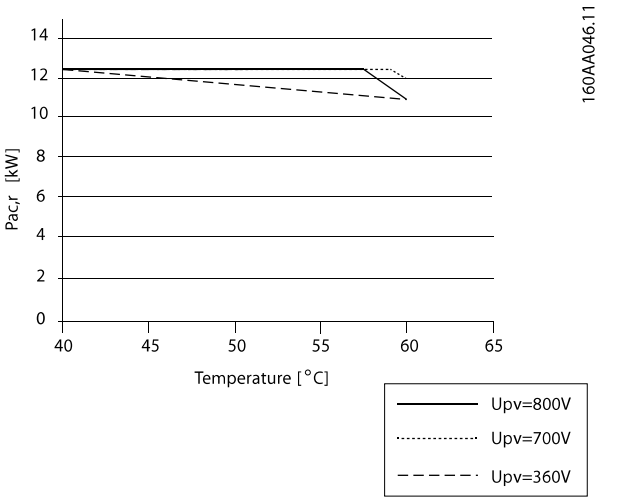



**Illustration 2.10 Derating Temperature, FLX 12.5**

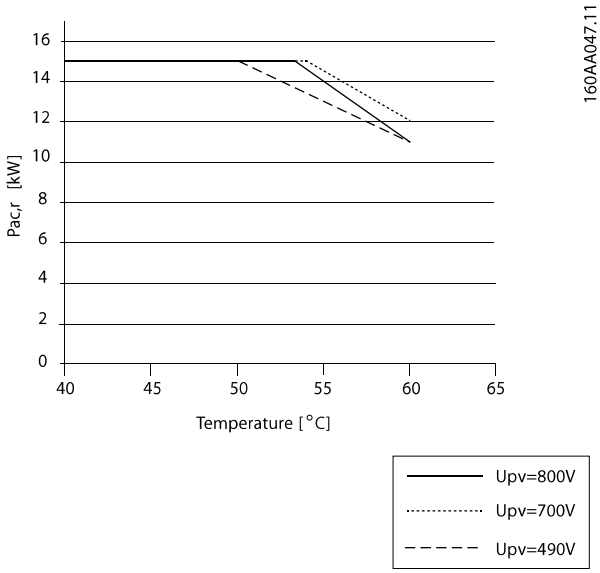



**Illustration 2.11 Derating Temperature, FLX 15**

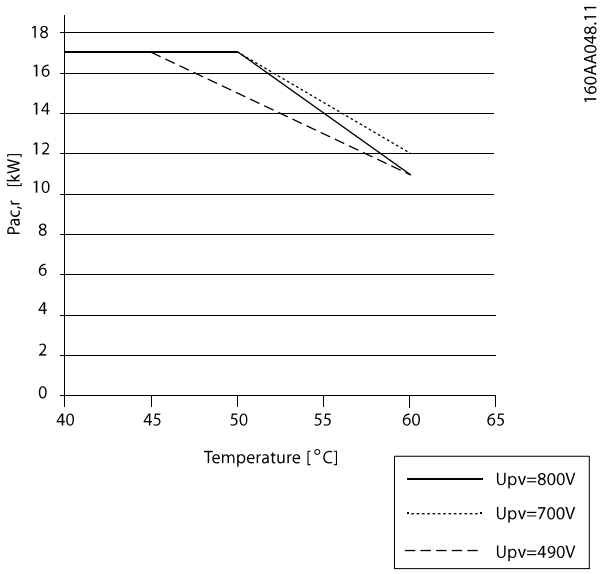



**Illustration 2.12 Derating Temperature, FLX 17**

**3. Grid Overvoltage**
When the grid voltage exceeds a DNO-defined limit *U1*, the inverter derates the output power. If the grid voltage increases and exceeds the defined limit *10 min mean (U2)*, the inverter ceases to energise the grid, in order to maintain power quality and protect other equipment connected to the grid.

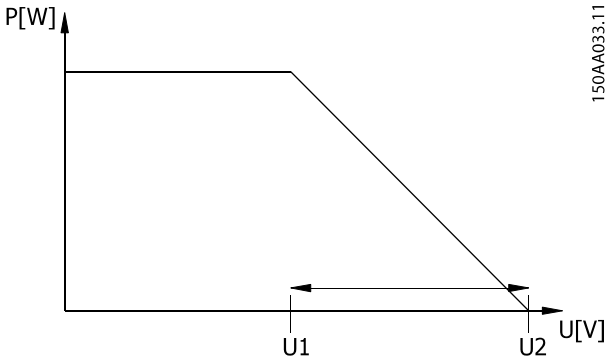



**Illustration 2.13 Grid Voltage above Limit Set by DNO**

| | |
|---|---|
| U1 | Fixed |
| U2 | Trip Limit |

At grid voltages lower than the nominal voltage (230 V), the inverter will derate to avoid exceeding the current limit.

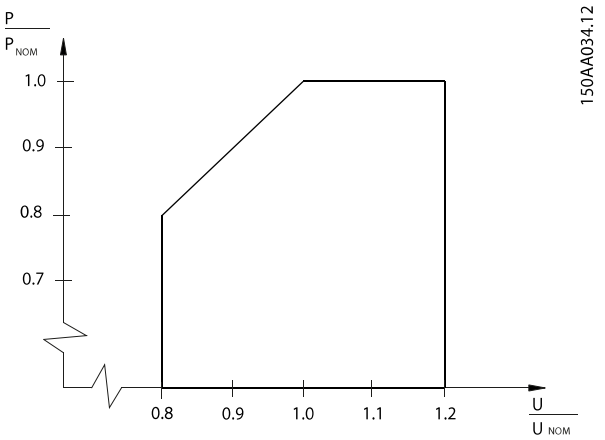



**Illustration 2.14 Grid Voltage Lower than $U_{nom}$**

## 2.3.6 MPPT

A Maximum Power Point Tracker (MPPT) is an algorithm, which is constantly trying to maximise the output from the PV array. The algorithm updates the PV voltage fast enough to follow rapid changes in solar irradiance.

Graph pending. Not ready before manual closure.

## 2.3.7 Yield Improving Features

### 2.3.7.1 PV Sweep

The characteristic power curve of a PV string is non-linear, and in situations where PV panels are partly shadowed, for example by a tree or a chimney, the curve can have more than 1 local maximum power point (local MPP). Only 1 of the points is the true global maximum power point (global

2

MPP). Using PV sweep the inverter locates the global MPP, rather than just the local MPP. The inverter then maintains production at the optimum point, the global MPP.

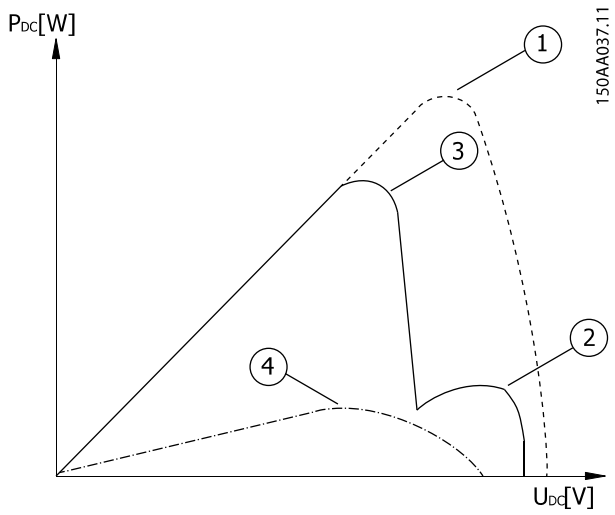



**Illustration 2.15 Inverter Output, Power (W) versus Voltage (V)**

| | |
|---|---|
| 1 | Fully irradiated solar panels - Global MPP |
| 2 | Partly shaded solar panels - Local MPP |
| 3 | Partly shaded solar panels - Global MPP |
| 4 | Cloudy conditions - Global MPP |

PV sweep functionality comprises 2 options of scanning the entire curve:

- Standard sweep – regular sweep at a pre-programmed interval.
- Advanced sweep – sweep for a period with a user defined interval.

**Standard Sweep**
Use standard sweep to optimise yield when there are permanent shadows on the PV panel. The characteristic will then be scanned at the defined interval to ensure production remains at the global MPP.

**Advanced Sweep**
Advanced PV Sweep is a standard PV sweep functionality extension. The FLX series inverter can be programmed to perform a PV sweep for a period with a user-defined interval. This is relevant when a panel shading period (from solid objects like trees or chimneys) is known. The sweep functionality will only be activated for a specific period to reduce further losses in yield. Up to 3 different sweep intervals can be set.

### 2.3.7.2 Adaptive Consumption Compensation (ACC)

Adaptive Consumption Compensation will optimise the plant yield while complying with the DNO requirements. The power output of the inverters is controlled as a function of actual self-consumption and power limit imposed by the DNO at PCC, e.g. a 70% limit of the installed PV power. In case of self-consumption, measured with an energy meter, the output power of the inverter will be increased for the duration of the increased self-consumption.
By default, the FLX Pro does not include the sensor module which contains the S0 input required by the ACC feature.
The sensor module can be purchased and installed inside the inverter, on the Option slot.

This feature can be enabled or disabled and the S0 input can be configured with the number of Pulses/kWh.

This feature can be used in combination with DPD.

### 2.3.7.3 Dynamic Power Distribution (DPD)

DPD is relevant for installations with more than 1 inverter that have different orientation of panels. DPD ensures that the total output power at the PCC is always kept at maximum, also under grid management conditions (EEG2012 fixed limits and PLA). If 1 section is in the shade, the inverter with full productivity has the load potential. The inverter will not have to cut down to e.g. 70%, as the plant (at PCC) is already output-reduced due to the shaded section. Finally, this feature allows increasing the yield by optimising power output under DNO restrictions.

This feature can be enabled and disabled.

This feature can be used in combination with ACC and is applicable for up to 10 inverters.

### 2.3.8 Internal Overvoltage Protection

**PV Overvoltage Protection**
PV overvoltage protection is a feature that actively protects the inverter against overvoltage. The function is independent of grid connection and remains active as long as the inverter is fully functional.
During normal operation the MPP voltage will be in the 250–800 V range and the PV overvoltage protection remains inactive. If the inverter is disconnected from grid the PV voltage will be in an open-circuit scenario (no MPP tracking). Under these conditions and with high irradiation and low-module temperature, the voltage may rise and exceed 900 V, potentially stressing the inverter. At this point, overvoltage protection activates.
When the PV overvoltage protection activates, the input voltage is virtually short-circuited, and forced to reduce to approximately 5 V. Just enough power remains to supply the internal circuits. The input voltage reduction is performed within 1.0 ms.
When the normal grid condition is re-established, the inverter will exit the PV overvoltage protection, returning MPP voltage to a level in the 250-800 V range.

**Intermediate Overvoltage Protection**
During start-up (before the inverter is connected to grid) and while PV is charging the intermediate circuit, the overvoltage protection may be activated to prevent overvoltage in the intermediate circuit.

## 2.4 Functional Safety Settings

The inverter is designed for international use and it can handle a wide range of requirements related to functional safety and grid behaviour. Parameters for functional safety and some grid code parameters are predefined and do not require any alteration during installation. However, some grid code parameters will require alterations during installation to allow optimisation of the local grid.

To meet these different requirements, the inverter is equipped with preset grid codes to accommodate standard settings. Since alteration of parameters can result in violation of legal requirements, as well as affect the grid negatively and reduce inverter yield, alterations are password-protected.

Depending on parameter type, some alterations are restricted to factory changes. In case of parameters used for optimisation of the local grid, alterations are allowed for installers. Alterations of parameters will automatically alter the grid code to “Custom”.

Follow the procedure described below for each change of grid code, either directly or via changes to other functional safety settings. For more information, refer to *2.3.4 International Inverter*.

Procedure for PV plant owner

1. Determine the desired grid code setting. The person responsible for the decision to change the grid code accepts full responsibility for any future conflicts.
2. Order the change of setting with the authorised technician.

Procedure for authorised technician

1. Contact the service hotline to obtain a 24-hour level 2 password and username.
2. Access and change the grid code setting via the web interface or the display.
3. Complete and sign the form ‘Change of Functional Safety Parameters’.
    - For access via web server
        - Generate a settings report.
        - Fill out the form generated by the web interface on the PC.
4. Send the following to the DNO:
    - The form ‘Change of Functional Safety Parameters’, completed and signed.
    - Letter requesting copy of authorisation to be sent to the PV plant owner.

## 2.5 User Interfaces

**The user interface comprises:**

- Local display. Enables manual setup of the inverter.
- Web interface. Enables access to multiple inverters via Ethernet.

For access and menu information, refer to the *FLX User Guide*.

### 2.5.1 Security Level

3 predefined security levels filter user access to menus and options.

**Security levels:**

- Level [0]: General access. No password is required.
- Level [1]: Installer or service technician. Password access required.
- Level [2]: Installer or service technician. Password extended access required.

Throughout the manual, a [0], [1] or [2] inserted after the menu item indicates the minimum security level required for access.

When logged on to the web interface as Admin, access is at security level [0].

Access to levels [1] and [2] requires a service logon, comprising a user ID and a password.

- The service logon provides direct access to a specific security level for the duration of the current day.
- Obtain the service logon from Danfoss.
- Enter the logon via the display, or the web interface logon dialog.
- When the service task is complete, log off at [Setup → Security].
- The inverter automatically logs the user off after 10 minutes of inactivity.

2

Security levels are similar on the display and the web interface.
A security level grants access to all menu items at the same level as well as all menu items of a lower security level.

***NOTICE***

**The display activates up to 10 seconds after power up.**

The integrated display on the inverter front gives the user access to information about the PV system and the inverter.

The display has 2 modes:

1. **Normal:** The display is in use.
2. **Power saving:** After 10 minutes of display inactivity the back light of the display turns off to save power. Reactivate the display by pressing any key.

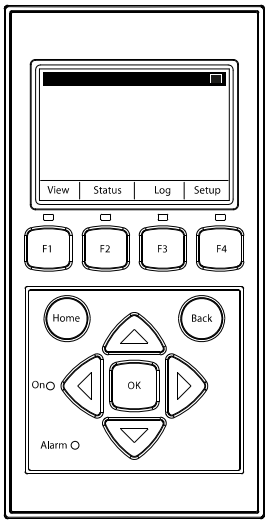



**Illustration 2.16 Overview of Display Buttons and Functionality**

| Key | Function | LED |
|---|---|---|
| **F1** | View 1/View 2 - Screen | When keys F1-F4 are selected, the LED above the key will light up |
| **F2** | Status Menu | |
| **F3** | Production Log Menu | |
| **F4** | Setup Menu | |
| **Home** | Return to View Screen | |
| **OK** | Enter/select | |
| **Arrow up** | A step up/increase value | |
| **Arrow Down** | A step down/decrease value | |
| **Arrow Right** | Moves cursor right | |
| **Arrow Left** | Moves cursor left | |
| **Back** | Return/de-select | |
| **On - Green LED** | | On/flashing = On grid/ Connecting |
| **Alarm - Red LED** | | Flashing = Fail safe |
| | The inverter is configured as master. This icon appears in the top right corner. | |
| | The inverter is a follower, connected to a master. This icon appears in the top right corner. | |

**Table 2.1 Overview of Display Buttons and Functionality**

***NOTICE***

**The contrast level of the display can be altered by pressing the arrow up/down button while holding down the F1 button.**

The menu structure is divided into 4 main sections:

1. **View** - presents a short list of information, read only.
2. **Status** - shows inverter parameter readings, read only.
3. **Log** - shows logged data.
4. **Setup** - shows configurable parameters, read/ write.

See the following sections for more detailed information.

## 2.5.2 Web Interface

Refer also to the *FLX User Guide* for setup and more detailed information.
The FLX series inverter is equipped with an integrated datalogger and a web interface. Up to 100 inverters can work together in a master/follower network. The master can be connected via Ethernet to a PC or to a router. Access the interface through a web browser (Microsoft Internet Explorer, Mozilla Firefox or Google Chrome).

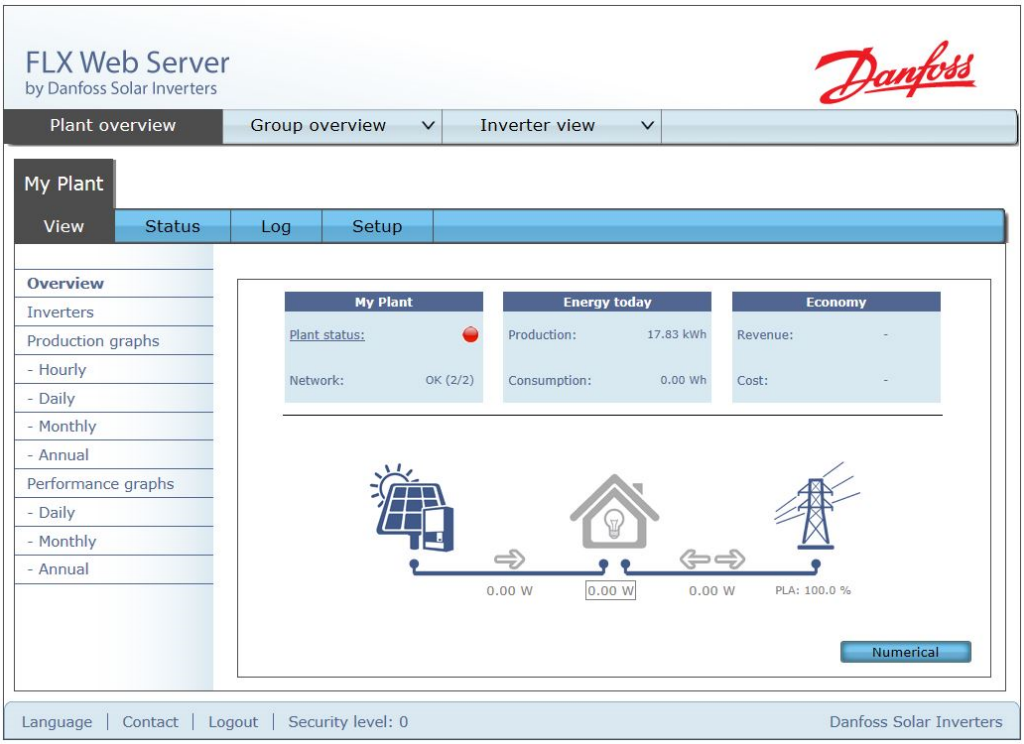



**Illustration 2.17 Overview**

Monitoring and configuration on plant level down to inverter level can be performed. For example, providing information about:

- Production
- Revenue
- $CO_2$ savings
- Performance
- Status overview
- Logs of the plant

Further commissioning of single or multiple inverters can be performed. The configuration wizard will configure all inverters found in the network. Replication of settings will copy the master settings to one or more inverters in the network.

- Plant level: The master inverter collects data from the follower inverters in one master/follower network and shows accumulated data.
- Group level: Inverters can be bundled together into groups and have to be bundled at least into 1 group. On this level, an overview of production and performance is given.
- Inverter level: The overview of production and performance, the logs, and the setup can be shown for a single inverter.

2

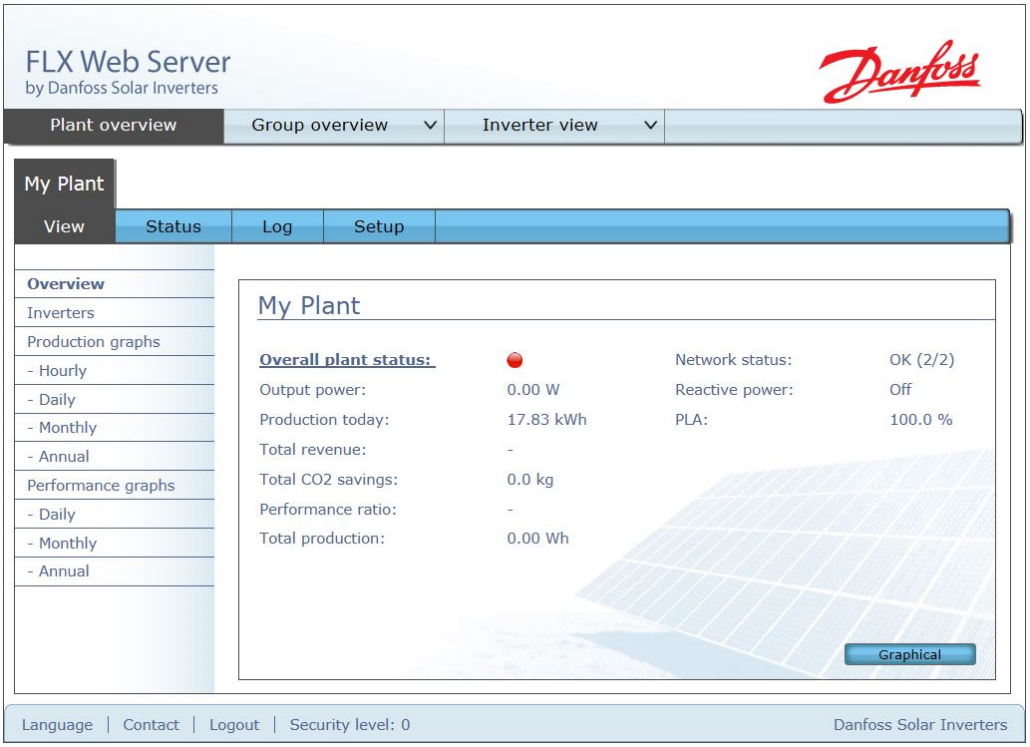



**Illustration 2.18 Overall Plant Status**

## 2.6 Ancillary Services

Ancillary services comprise inverter functionalities which aid transport of power on grids and contribute to grid stability. The ancillary services required for a particular PV system are determined by the point of common coupling (PCC) and the grid type to which the system is connected. The PCC is the point where the PV system is connected to the public electricity grid.

In residential installations, the domestic circuits and the solar inverters are usually connected to the grid at 1 common point. The installation becomes part of the low-voltage (LV) distribution system. Commercial installations are normally larger and therefore connected to the medium-voltage (MV) system. Large-scale commercial systems, such as power plants, can be connected to the high-voltage (HV) grid.

Each of the power systems has individual ancillary service requirements. Depending on the location and the DNO, some of these services will be mandatory and others are optional. Mandatory requirements are automatically configured through the selected grid code. Optional services are configured by the installer during commissioning.

Grid support can be divided into the following main groups, which will be covered in subsequent sections:

- Dynamic Network Support
- Active Power Control
- Reactive Power Control

### 2.6.1 Active/Reactive Power Theory

The principle in generating reactive power is that the phases between the voltage and the current are shifted in a controlled way.
Reactive power cannot transport consumable energy, but it generates losses in power lines and transformers and is normally unwanted.
Reactive loads can be either capacitive or inductive in nature, depending on the current leads or lags in relation to the voltage.
Utility companies have an interest in controlling reactive power in their grids, for example in:

- Compensation for inductive loading by injection of capacitive reactive power.
- Voltage control.

To compensate for this a generator exchanging reactive power operates either at a lagging power factor, also known as overexcited, or at a leading power factor, also known as underexcited.

The technical definition of reactive power, based on the definition of apparent power, is:

- Active power (P) measured in Watts [W].
- Reactive power (Q) measured in volt-ampere reactive [VAr].
- Apparent power (S) is the vector-sum of P and Q and is measured in volt-ampere [VA].
- φ is the angle between current and voltage and thus between P and S.

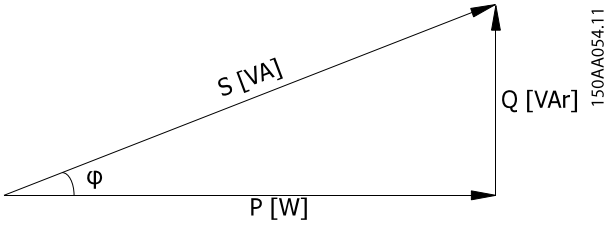



**Illustration 2.19 Reactive Power**

In the inverter, the reactive power is defined either as:

- **Q**: The amount of reactive power as a percentage of the nominal apparent power of the inverter.
- **PF, Power Factor***): The ratio between P and S (P/S), also referred to as: Cos(φ).

*) Displacement Power Factor at fundamental frequency.

## 2.7 Ancillary Services Overview

The following table outlines the individual ancillary services.

| | FLX Pro |
|---|---|
| **Apparent Power (S)** | |
| Fixed limit | ✓ |
| **Active Power (P)** | |
| Fixed limit | ✓ |
| Remotely controlled PLA | PLA option<br>CLX GM[1]<br>CLX Home GM[2]<br>CLX Standard GM[3] |
| **Reactive Power (Q)** | |
| Constant Q or PF | ✓ |
| Dynamic Q(U) | ✓[1] |
| Dynamic PF(P) | ✓ |
| Remotely controlled Q or PF | PLA option<br>CLX GM[1]<br>CLX Home GM[2]<br>CLX Standard GM[3] |
| Closed loop control Q or PF | ✓[4] |

**Table 2.2 Grid Management**

*1) Ethernet, max. 100 inverters per network.*

*2) RS-485, max. 3 inverters per network.*

*3) RS-485, max. 20 inverters per network.*

*4) By 3rd-party product.*

***NOTICE***

**Check local legal requirements before changing settings for ancillary services.**

## 2.8 Dynamic Network Support (FRT)

The grid voltage usually has a smooth waveform, but occasionally the voltage drops or disappears for several milliseconds. This is often due to short-circuit of overhead lines, or caused by operation of switchgear or similar in the high-voltage transmission lines. In such cases the inverter can continue to supply power to the grid using fault ride through (FRT) functionality.
Continuous power supply to the grid is essential:

- To help prevent a complete voltage blackout and stabilise the voltage in the grid.
- To increase the energy delivered to the AC grid.

**Zero Current Setting**
For special requirements from the DNO, a zero current 'LVRT' option is available. It provides no current in fault ride through situations.

The inverter has a high immunity against voltage disturbances as depicted in *2.8.1 Example - Germany MV*.

2

### 2.8.1 Example - Germany MV

How FRT works
*Illustration 2.20* shows the requirements to be followed by FRT. This example is for German medium-voltage grids.

- **Above line 1**
  For voltages above line 1, the inverter must not disconnect from the grid during FRT under any circumstances.
- **Area A**
  The inverter must not disconnect from grid for voltages below line 1 and left of line 2. In some cases the DNO permits a short-duration disconnection, in which case the inverter must be back on grid within 2 seconds.
- **Area B**
  To the right of line 2, a short-duration disconnection from grid is always permitted. The reconnect time and power gradient can be negotiated with the DNO.
- **Below line 3**
  Below line 3, there is no requirement to remain connected to grid.

When a short-duration disconnection from grid occurs,

- the inverter must be back on grid after 2 seconds;
- the active power must be ramped back at a minimum rate of 10% of nominal power per second.

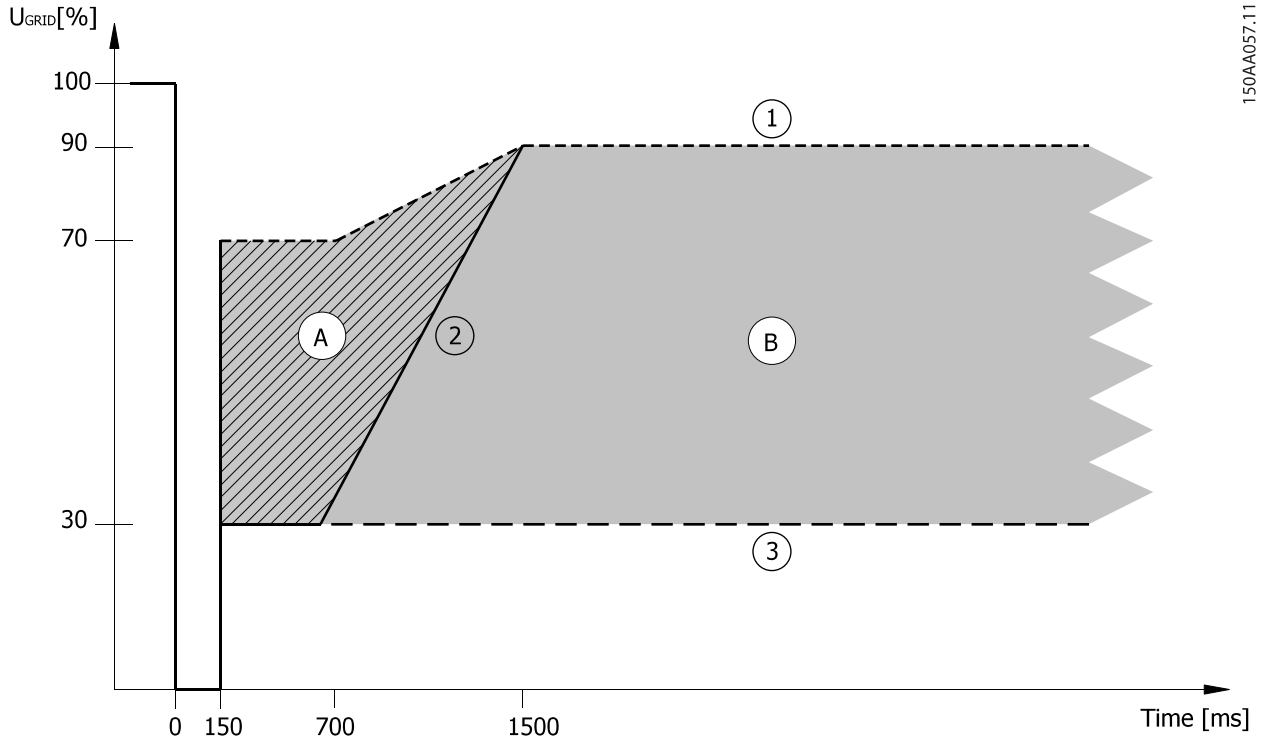



**Illustration 2.20 German Example**

***NOTICE***

**To enable reactive current during FRT, select a medium-voltage grid code.**

**Parameters related to FRT**
These parameters are set automatically upon selecting the grid code.

| Parameter | Description |
|---|---|
| FRT upper threshold level | Upper grid voltage magnitude for engaging a high-voltage FRT |
| FRT lower threshold level | Lower grid voltage magnitude for engaging a low-voltage FRT |
| Static reactive power, k | Ratio between additional reactive current to be injected during the FRT and the depth of the sag, k= ($\Delta I_B/I_N$) / ($\Delta U/U$) ≥ 2.0 p.u. |
| Transition time | Duration of period after the sag has cleared, where reactive current is still injected. |

**Table 2.3 Parameters related to FRT**

In addition to remaining on grid during the fault, the inverter can deliver reactive current to support the grid voltage.

## 2.9 Active Power Control

The inverter range supports active power control, which is used to control the active output power of the inverter. The control methods of the active output power are described below.

### 2.9.1 Fixed Limit

To ensure that the PV system is not producing more power than allowed, the output power can be limited to a fixed upper level set as:

- Absolute value [W].
- Percentage based on total installed PV power [%].
- Percentage based on nominal AC output power [%].

### 2.9.2 Dynamic Value

The output power is reduced as a variable of the grid frequency. There are 2 methods for reducing the output power: ramp and hysteresis. The grid code setting determines which method is implemented in a specific installation.

**Primary frequency control – ramp method**
The inverter reduces output power if the grid frequency exceeds $f_1$. Reduction occurs at a preconfigured rate, which is the ramp (R) shown in *Illustration 2.21*.
When the frequency reaches $f_2$, the inverter disconnects from grid. When the frequency decreases below $f_2$, the inverter reconnects to grid and ramps up power at the same rate as for the reduction.

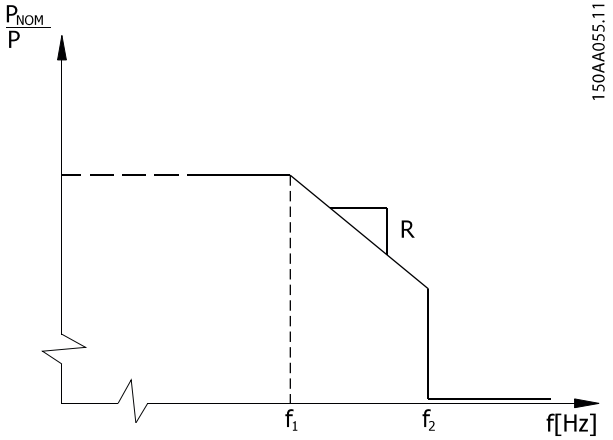



**Illustration 2.21 Primary Frequency Control – Ramp Method**

**Primary Frequency control – hysteresis method**
To support grid stabilisation, the inverter reduces output power if the grid frequency exceeds $f_1$. Reduction occurs at a preconfigured rate, which is the ramp (R) shown in *Illustration 2.22*. The reduced output power limit is maintained until the grid frequency has decreased to $f_2$. When the grid frequency has decreased to $f_2$, the inverter output power increases again following a time ramp T. If the grid frequency continues to increase, the inverter disconnects at $f_3$. When the frequency decreases below $f_2$, the inverter reconnects to grid and ramps up power at the same rate as for the reduction.

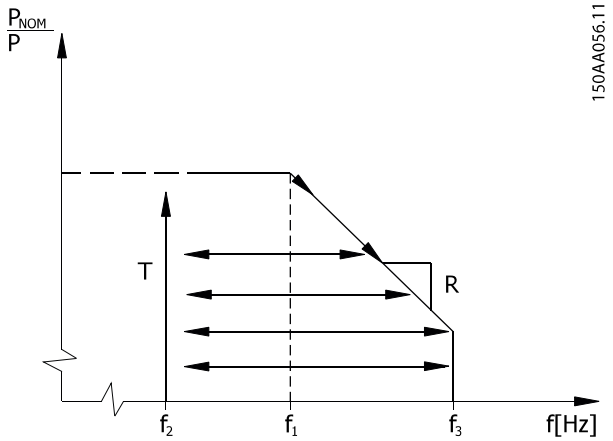



**Illustration 2.22 Primary Frequency Control – Hysteresis Method**

2

## 2.9.3 Remotely Controlled Adjustment of Output Power Level

The inverter supports remotely controlled adjustment of the output power level. This is the Power Level Adjustment function (PLA). The inverter can handle the control of output power, or it can be handled by CLX monitoring and grid management products or 3rd-party external device.

When using the master functionality to manage the control of the output power level, the PLA option or Danfoss CLX GM is required as interface device between the DNO signal interface (radio receiver) and the inverter. The master inverter can be configured to interpret the DNO signal information and will automatically distribute the commanded output power level (PLA) to all followers in the network. See *Illustration 2.23*.

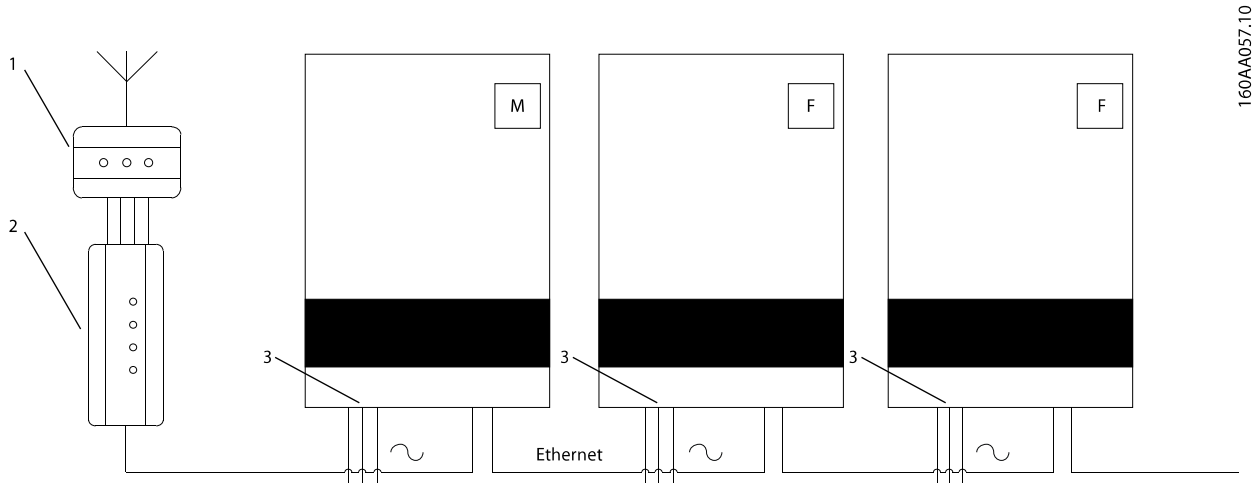



**Illustration 2.23 Example: Managing Ancillary services**

| | |
|---|---|
| 1 | DNO interface (radio receiver) |
| 2 | Danfoss CLX GM |
| 3 | Measurement Point |

**FLX with CLX monitoring and grid management products or 3rd-party external device**

Based on the input from a DNO signal interface, CLX monitoring and grid management products or 3rd-party external device send PLA commands directly to the inverter, e.g. via the RS-485 interface. Each inverter then uses this information to determine its output power limit. Both Danfoss and 3rd-party products are available for external control (for more information about relevant products, see the supplier manuals). See *Illustration 2.24*.

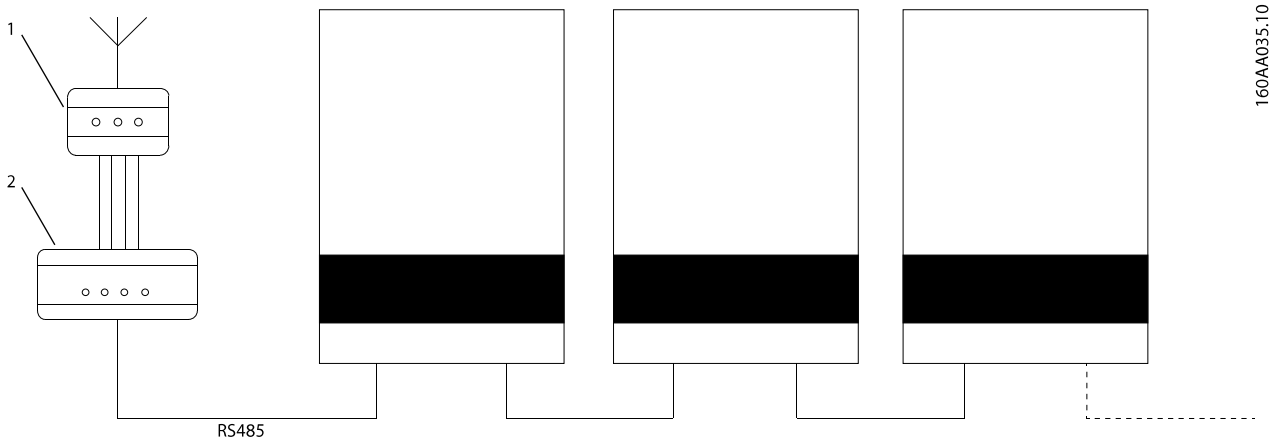



**Illustration 2.24 Example: Managing Power Using CLX Monitoring and Grid Management Products or 3rd-party External Device**

| | |
|---|---|
| 1 | DNO interface (radio receiver) |
| 2 | CLX monitoring and grid management product or 3rd-party device |

**Configuration**
Remotely controlled output power is configured in the CLX monitoring and grid management product or 3rd-party device. See manual for CLX product or 3rd-party device.

## 2.10 Reactive Power

The FLX series inverters support reactive power control, which is used to control the reactive output power of the inverter.

In the 2 operation modes described below, the control functions for reactive power cannot be in operation, which results in exchange of reactive power:

- The inverter is not delivering power to the grid but still connected to the grid: LCL, EMC filter components, and power supply contribute to reactive power exchange.
- The inverter is not connected to the grid, therefore only the power supply contributes to the reactive power exchange with 6 VAr.

### 2.10.1 Constant Value

The inverter can be set to provide a fixed reactive power value in 1 of the following ways:

- Off.
- Constant reactive power Q.
- Constant power factor PF.

**Off**
The inverter will not use any internal setpoint for reactive power, but an external setpoint source can be used. FLX inverters support a number of 3rd-party grid management units for managing reactive power. Set the 'setpoint type' to “Off”. This will enable the inverter to accept a setpoint for PF and Q, transmitted via RS-485 from the external source.

**Constant Reactive Power Q**
The inverter will generate a fixed level of reactive power, specified as a percentage of the inverter’s nominal apparent power (S). The value of constant reactive power Q can be set in the range from 60% (under-excited) to 60% (over-excited). The value can be maintained from 3% of nominal power.

**Constant Power Factor PF**
Constant power factor specifies a fixed relation between active and apparent power (P/S), i.e. a fixed Cos (φ). The power factor PF can be set in the range from: 0.8 under-excited to 0.8 over-excited. The reactive power generated by the inverter is thus dependent on the active power generated.

Example:

- PF=0.9.
- Generated active power (P) = 10.0 kW.
- Apparent power (S) = 10.0/0.9 = 11.1 kVA.
- Reactive power (Q) = $\sqrt{(11.1^2-10.0^2)}$ = 4.8 kVAr.

### 2.10.2 Dynamic Value

Depending on the dynamic reactive controls required it can be achieved:

- directly on the inverter through the master inverter, or
- via a CLX monitoring and grid management product, or
- via 3rd-party device.

**Setpoint curve PF(P)**
The PF(P) curve is either pre-configured in each inverter (via the selected grid code) or configured manually in the web interface. The PF(P) control is thus operating on inverter level, measuring the output power of the unit and delivering reactive power accordingly. See *Illustration 2.23*.

**Setpoint curve Q(U)**
The inverter controls reactive power as a function of the grid voltage U. The values for the setpoint curve are determined by the local utility company and must be obtained from them. The Q(U) curve is configured on plant level. The master measures grid voltage and determines and delivers reactive P(Q) accordingly. The Q value is sent to all followers in the network. See *Illustration 2.23*.

### 2.10.3 Remotely Controlled Adjustment of Reactive Power

All inverters support remotely controlled adjustment of reactive power.

**FLX series inverter**
When using the master functionality to manage the control of reactive power, the Danfoss CLX GM or the internal PLA option is needed as interface device between the DNO signal interface (radio receiver) and the master inverter. The master inverter can be configured to interpret the DNO signal information and will automatically distribute the commanded reactive power setpoint to all followers in the network. See *Illustration 2.23*. For more information, see the *Danfoss CLX GM User Manual*.

2

**FLX with CLX monitoring and grid management product or 3rd-party device**

Based on the input from a DNO signal interface, an external device sends reactive power commands directly to the inverter, e.g. via the RS-485 interface. Each inverter then uses this information to determine its reactive power level. Both Danfoss and 3rd-party products are available for external control. See *Illustration 2.24*. For more information about relevant products, see the supplier manuals.

**Configuration**

Remotely controlled reactive power is configured in the CLX monitoring and grid management product or 3rd-party device, see manual for CLX monitoring and grid management product or 3rd-party device.

## 2.11 Fallback Values

When remotely controlled active power or reactive power is selected as reference value for the inverter, fixed fallback values can be used in the event of communication failure:

- between the master inverter and the PLA option, or
- between the master inverter and the Danfoss CLX GM, or
- between the master inverter and the follower inverter.

This feature will be available from SW version 2.10.

# 3 System Planning

## 3.1 Introduction

The aim of this section is to provide general information for planning integration of the inverter into a PV system:

- PV system design, including earthing.
- AC grid connection requirements; including choice of AC cable protection.
- Ambient conditions, such as ventilation.

## 3.2 DC Side

### 3.2.1 Requirements for PV Connection

The nominal/maximum input specification per PV input and total is shown in *Table 3.1*.

To avoid damaging the inverter, observe the limits in the table when dimensioning the PV generator for the inverter.

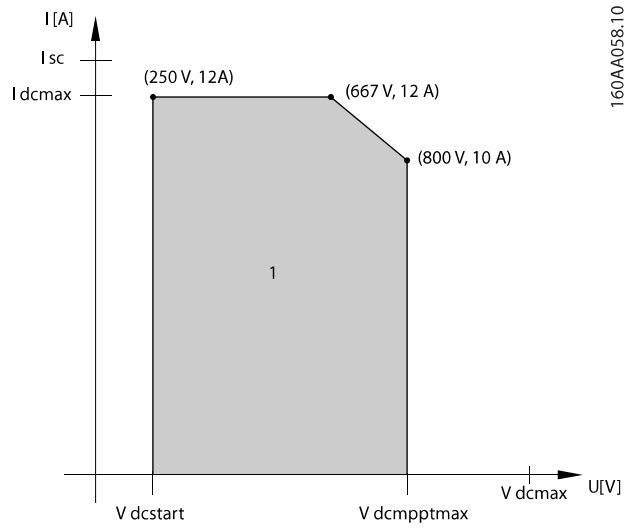
For guidance and recommendations on dimensioning the PV generator (module array), to align with the following inverter capability, refer to *3.2.2 Determining Sizing Factor for PV System*.



| **Parameter** | FLX series | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **5** | **6** | **7** | **8** | **9** | **10** | **12.5** | **15** | **17** |
| Number of PV inputs | 3 | | | | | | | | |
| Maximum input voltage, open circuit ($V_{dcmax}$) | 1000 V | | | | | | | | |
| Minimum MPP voltage ($V_{Vdcstart}$ Turn on voltage DC) *) | 250 V | | | | | | | | |
| Maximum MPP voltage ($V_{mppmax}$) | 800 V | | | | | | | | |
| Max./nom. input current ($I_{dcmax}$) | 12 A per PV input | | | | | | | | |
| Max. short-circuit current ($I_{sc}$) | 13.5 A per PV input | | | | | | | | |
| Max./nom. PV input power per MPPT ($P_{mpptmax}$) | 5.2 kW | 6.2 kW | 7.2 kW | 8 kW | | | | | |
| Max./nom. converted PV input power, total ($\Sigma P_{mpptmax}$) | 5.2 kW | 6.2 kW | 7.2 kW | 8.3 kW | 9.3 kW | 10.4 kW | 12.9 kW | 15.5 kW | 17.6 W |

**Table 3.1 PV Operating Conditions**

*) *For asymmetrical layouts consider turn-off voltage of 220 V, see Table 5.1 and Table 5.2.*




| | |
|---|---|
| 1 | Operating range per MPP tracker |

**Illustration 3.1 Operating Range per MPP Tracker**

**Maximum Open-circuit Voltage**
The open-circuit voltage from the PV strings must not exceed the maximum open-circuit voltage limit of the inverter. Check the specification of the open-circuit voltage at the lowest PV module operating temperature. If module operating temperature is not well defined, check local common practice. Also check that the maximum system voltage of the PV modules is not exceeded. Highest efficiency can be achieved by designing long strings. Special requirements apply to thin film modules. See *3.2.3 Thin Film*.

**MPP Voltage**
The string MPP voltage must be within the operational range of the MPPT of the inverter, defined by minimum voltage operation MPP (250 V) and maximum voltage operating MPP (800 V), for the temperature range of the PV modules.
To utilise the full range, asymmetrical layouts must be considered including start-up voltage of 250 V for at least 1 string. In that case the MPP tracker is active down to a turn-off voltage of 220 V.

**Short-circuit Current**
The maximum short-circuit current ($I_{sc}$) must not exceed the absolute maximum that the inverter is able to withstand. Check the specification of the short-circuit current at the highest PV module operating temperature.

Observe the power limits for individual PV inputs. However, the converted input power will be limited by maximum converted PV input power, total ($\Sigma P_{mpptmax}$) and not the sum of maximum PV input power per MPPT ($P_{mpptmax1} + P_{mpptmax2} + P_{mpptmax3}$).

**Max./Nom. Converted PV Input Power, Total**
The 2 and/or 3 MPP trackers can handle more power in total than the inverter can convert. The inverter will limit the power intake by shifting the MPP when surplus PV power is available.
For further information about PV over-sizing and related consequences see *3.2.2 Determining Sizing Factor for PV System*.

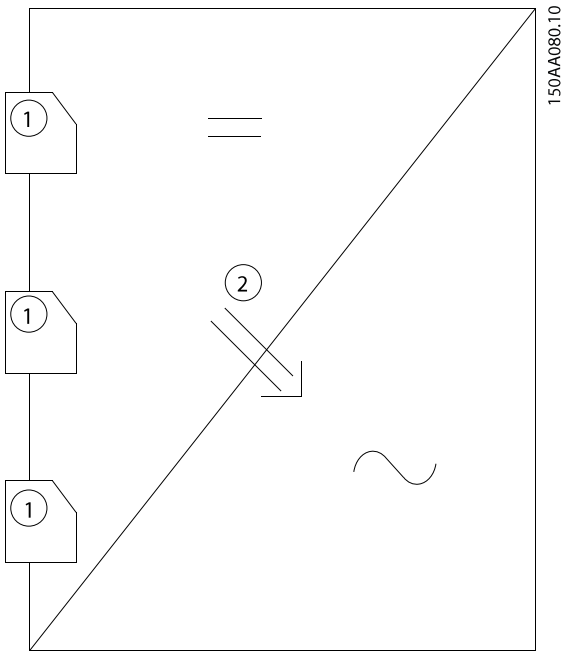



**Illustration 3.2 Max./Nom. Converted PV Input Power, Total**

| | |
|---|---|
| 1 | Operating range for each individual MPP tracker |
| 2 | $\Sigma_{mpptmax}$, converted |

**Reversed Polarity**
The inverter is protected against reversed polarity and will not generate power until the polarity is correct. Reversed polarity damages neither the inverter nor the connectors.

**⚠CAUTION**

**Remember to disconnect the PV load switch before correcting polarity!**

**PV to Earth Resistance**
Monitoring of the PV to earth resistance is implemented for all grid codes, as supplying energy to the grid with too low a resistance could be harmful to the inverter and/or the PV modules. PV modules designed according to the IEC61215 standard are only tested to a specific resistance of minimum 40 MΩ*m$^2$. Therefore, for a 24 kWp power plant with a 14% PV module efficiency, the total area of the modules yields 171 m$^2$, which again yields a minimum resistance of 40 MΩ*m$^2$/171 m$^2$ = 234 kΩ.

The PV design must be within the required limit of the applied grid code. See *2.3.4 International Inverter*.

**Earthing**
It is not possible to earth any of the terminals of the PV arrays. However, it may be compulsory to earth all conductive materials, e.g. the mounting system to comply with the general codes for electrical installations.

**Parallel Connection of PV Arrays**
The PV inputs of the inverter can be externally connected in parallel. The advantages and disadvantages of parallel connection are:

- **Advantages**
  - Layout flexibility.
  - Parallel connection makes it possible to apply a single 2-wire cable from the PV array to the inverter (reduces the installation cost).
  - Parallel connection makes it possible to use only 1 cable for longer distances (reduces cable cost).
  - Increases the layout possibilities in order to perform overdimensioning.
- **Disadvantages**
  - Monitoring of each individual string is not possible.
  - String fuses/string diodes may be necessary to avoid risk of backfeed current.

After making the physical connection, the inverter carries out an autotest of the PV configuration and configures itself accordingly.

If the PV input configuration is set to “automatic” (default setting), the inverter will detect the parallel and individual strings by itself as described.

If the PV input configuration is set to “manual”, the user must configure each PV input to either parallel or individual according to the actual wiring.

The following graphics represent examples of different parallel mode configurations. **All graphics are simplified and they only show 1 of the 2 PV polarities. Consequently implementation requires the amount of cables to be doubled.**

The legend below applies to all parallel mode drawings in this section.

| | |
|---|---|
| 1 | Inverter |
| 2 | Cable |
| 3 | PV modules |
| 4 | 4 strings in parallel (or 3) |
| 5 | 1 string (or 2 in parallel) |

3

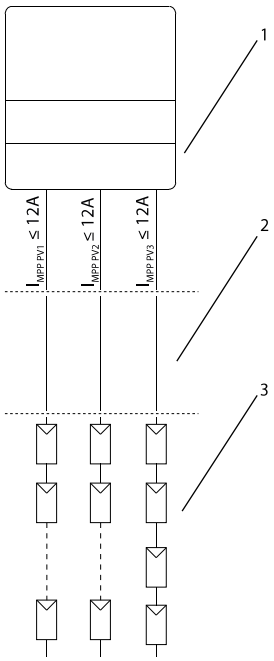



**Illustration 3.3 Case 1: Individual Configuration**

Direct cable connection from PV modules to inverter.
Asymmetric layouts are possible:

- Different string lengths for all inputs.
- Different modules types for all inputs (same types per string).
- Different module orientation for all inputs.

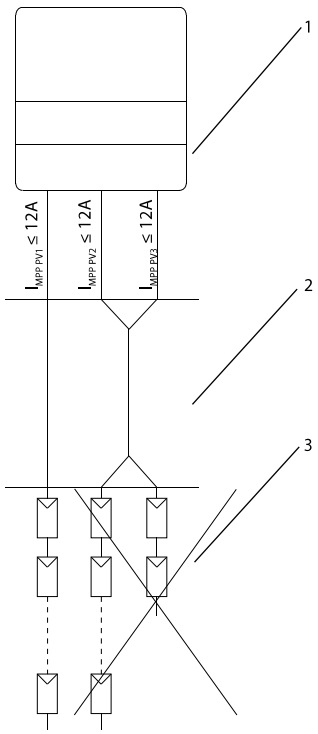



**Illustration 3.4 Not Allowed!**

Asymmetrical configurations in parallel mode are never allowed.

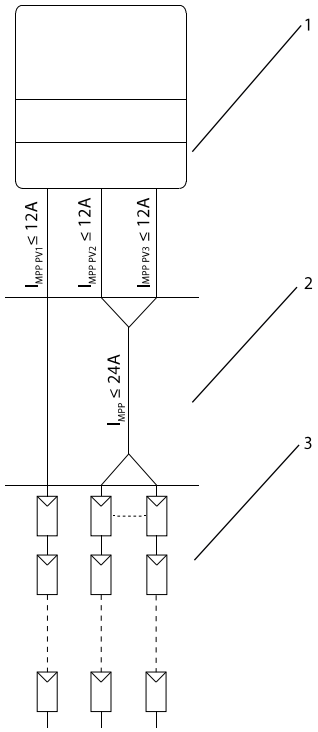



**Illustration 3.5 Case 2: Parallel Connection, Maintaining 2 Independent Trackers**

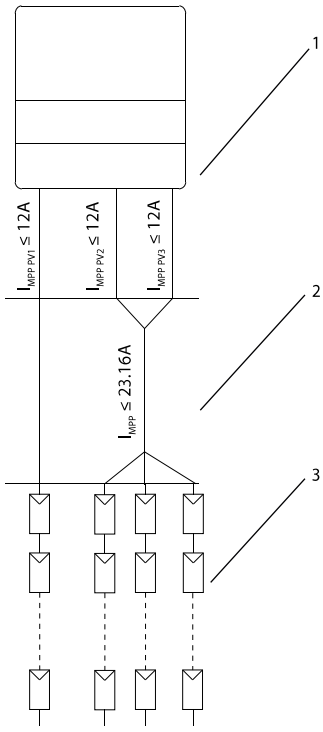



**Illustration 3.6 Case 2, Example 1: Parallel Connection, Maintaining 2 Independent Trackers**

With this configuration 2 independent trackers can be maintained.

Depending on the current of the modules there can be more than 2 strings in parallel using a simple splitter or Y-connector.

- Same string lengths on PV1 and PV2.
- Shorter string lengths on PV3 and uses different modules or module orientation.

**This is an example with 6" cell modules**. Each plant has to be designed individually and the specific solar cell characteristics as well as the environmental conditions have to be taken into consideration.

With this configuration 2 independent trackers can be maintained.

In this configuration an external combiner box and string fuses could be needed.

Parallel String 6" Cells: 23 modules, $V_{oc}$ = 1000, $I_{MPP}$ = 7.72 A, P = 5.29 kWp per string.

Total power: 4 x 23 x 230 Wp = 21.2 kWp (124.5% sizing factor for FLX 17). 7.9 kWp per MPPT in MPPT 2 and 3 (STC). 5.3 kWp in MPPT 1.

A very limited amount of modules are available to be used in this configuration.

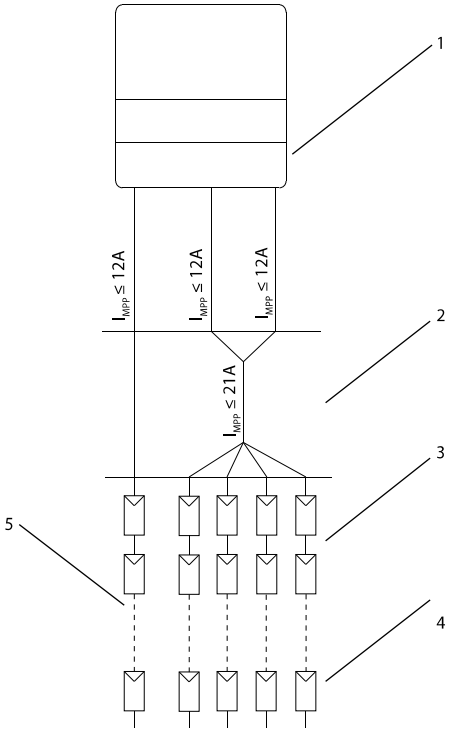



**Illustration 3.7 Case 2, Example 2: Parallel Connection, Maintaining 2 Independent Trackers**

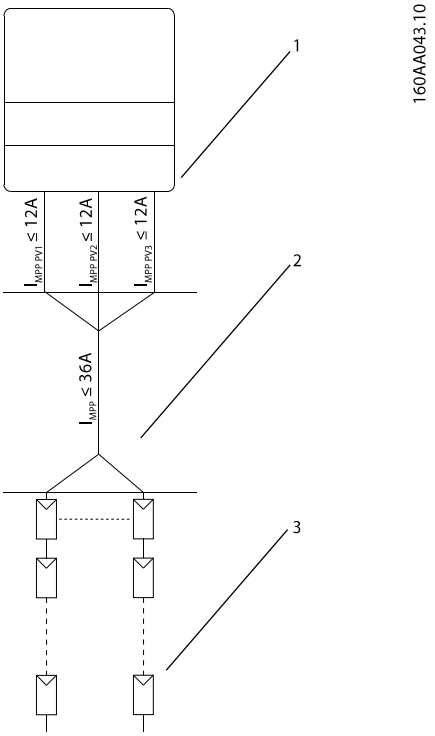



**Illustration 3.8 Case 3: Parallel Connection with 1 Common MPPT Tracker**

**This is an example with 5" cell modules**. Each plant has to be designed individually and the specific solar cell characteristics as well as the environmental conditions have to be taken into consideration.

In this configuration an external combiner box and string fuses could be needed.

Parallel String 5" Cells: 18 modules, $V_{oc}$ = 1000, $I_{nom}$ = 5.25 A, $I_{sc}$ = 5.56 A, P = 3.51 kWp per string.

Modules used: 195 Wp (high performance modules) among 5" cells. 4 strings of 19 modules are possible (3.71 kWp per string). In parallel and 1 individual string. Max peak power: 5 x 19 x 195 = 18.53 kWp (130% sizing factor for FLX 17).

Depending on the current of the modules there can be more than 2 strings in parallel.

Fuses may be needed in this configuration, when the maximum reverse current allowed for the PV modules is exceeded (normally 3 or more strings in parallel for 6"-60 cells modules).

This configuration needs an external combiner box.

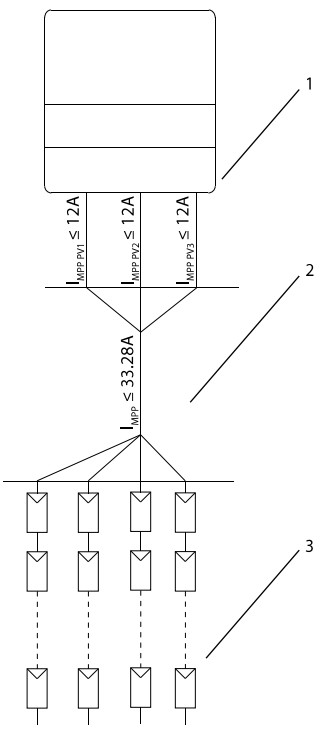



**Illustration 3.9 Case 3, Example 1: Parallel Connection with 1 Common MPPT Tracker**

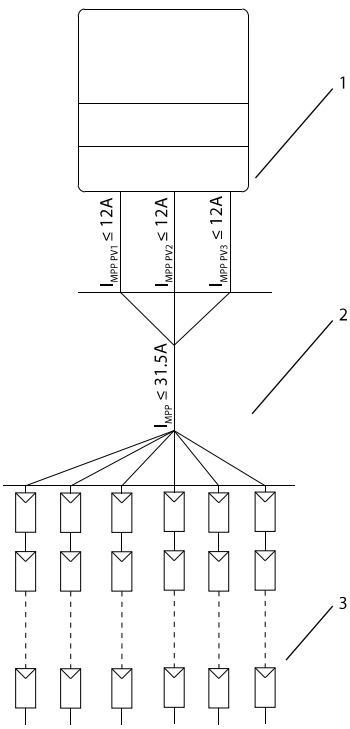



**Illustration 3.10 Case 3, Example 2: Parallel Connection with 1 Common MPPT Tracker**

**This is an example with 6" cell modules**. Each plant has to be designed individually and the specific solar cell characteristics as well as the environmental conditions have to be taken into consideration.

An external combiner box is needed in this configuration. Fuses may be needed.

Parallel String: 6" Cells: 23 modules, $V_{oc}$ = 1000, $I_{MPP}$ = 8.32 A, P = 5.75 kWp per string.

Module in the example: 250 Wp. In this configuration there are 7.7 kWp per MPPT. (23 kWp; 135% sizing factor for FLX 17).

**This is an example with 5" cell modules**. Each plant has to be designed individually and the specific solar cell characteristics as well as the environmental conditions have to be taken into consideration.

An external combiner box is needed in this configuration. Fuses may be needed.

Parallel String: 5" Cells: 18 modules, $V_{oc}$ = 1000, $I_{nom}$ = 5.25 A, P = 3.51 kWp per string.

Modules used: 195 Wp (high-performance modules) among 5" cells. 6 strings of 19 modules are possible (3.7 kWp per string). Max. peak power: 6 x 19 x 195 Wp = 22.23 kWp (130% sizing factor for FLX 17).

3

**PV Cable Dimensions and Layout**
The power loss in the PV cables should not exceed 1% of nominal value in order to avoid losses. For an array of 6000 W at 700 V, this corresponds to a maximum resistance of 0.98 Ω. Assuming aluminium cable is used (4 $mm^2$ → 4.8 Ω/km, 6 $mm^2$ → 3.4 Ω / km), the maximum length for a 4 $mm^2$ cable is approximately 200 m and for a 6 $mm^2$ cable approximately 300 m. The total length is defined as twice the physical distance between the inverter and the PV array plus the length of the PV cables included in the modules. Avoid looping the DC cables as they can act as an antenna of radio-noise emitted by the inverter. Cables with positive and negative polarity should be placed side by side with as little space between them as possible. This also lowers the induced voltage in case of lightning and reduces the risk of damage.

| DC | | Max. 1000 V, 12 A |
|---|---|---|
| Cable length | 4 $mm^2$ -4.8 Ω /km | <200 m* |
| Cable length | 6 $mm^2$ -3.4 Ω /km | >200-300 m* |

**Table 3.2 Cable Specifications**

** The distance between inverter and PV array and back, plus the cumulative length of PV array cabling.*

## 3.2.2 Determining Sizing Factor for PV System

When determining the PV system size factor, a specific analysis is preferred, especially for large PV installations. Local rules of thumb for choosing the sizing factor can be determined, depending on local conditions, e.g.:

- Local climate
- Local legislation
- System price level

To select the optimal configuration/sizing factor, an investment analysis must be made. Big sizing factors will usually reduce specific investment costs (€/kWp) but could have lower specific yield (kWh/kWp) due to derating losses in the inverter (excessive DC power or overheating) and so, lower income.

Small sizing factors result in greater investment costs. However, specific yield is potentially greater due to little or no derating loss.

Installations in regions with irradiance levels over 1000 $W/m^2$ are frequently experienced. If hot ambient temperatures are not expected during the irradiance peaks, these installations should have lower levels of sizing factor than installations in regions where this irradiance level is infrequent.

A lower sizing factor should be considered for tracking systems, because tracking systems allow more frequent high irradiance levels. In addition, derating due to overheating of the inverter should be considered for tracking systems in hot climates, and could also reduce the recommended sizing factor.

FLX supports different sizing factors. Each PV input can support up to 8000 W, with a maximum short-circuit current of 13.5 A, an MPP current of 12 A, and an open-circuit voltage of 1000 V DC.

## 3.2.3 Thin Film

The use of FLX series inverters with thin film modules has been approved by some manufacturers. Declarations and approvals can be found at www.danfoss.com/solar. If no declaration is available for the preferred module, it is important to obtain approval from the module manufacturer before installing thin film modules with the inverters.
The PV power circuits (the boosters) of the inverters are based on an inverted asymmetrical boost converter and bipolar DC-link. The negative potential between the PV arrays and earth is therefore considerably lower, compared to other transformerless inverters.

**⚠CAUTION**

**With certain types of thin film technology module voltage during initial degradation may be higher than the rated voltage in the data sheet. This must be taken into consideration when designing the PV system, since excessive DC voltage can damage the inverter. Module current may also lie above the inverter current limit during the initial degradation. In this case the inverter decreases the output power accordingly, resulting in lower yield. Therefore, when designing, take inverter and module specifications both before and after initial degradation into consideration.**

## 3.2.4 Internal Overvoltage Protection

The inverter is manufactured with internal overvoltage protection on the AC and PV side. If the PV system is installed on a building with an existing lightning protection system, the PV system must also be properly included in the lightning protection system. The inverter itself does not include SPD. Varistors in the inverter are connected between phase and neutral cables, and between PV plus and minus terminals. 1 varistor is positioned between the neutral and PE cables.

| Connection point | Overvoltage category according to EN50178 |
|---|---|
| AC side | Category III |
| PV side | Category II |

**Table 3.3 Overvoltage Category**

**⚠CAUTION**

**When mounting the inverter on a grounded metallic surface, ensure that the inverter's earthing point and mounting plate are directly connected. Failure to do so can potentially result in material damage to the inverter, via arcing between the mounting plate and the inverter enclosure.**

**Description of PV Overvoltage Protection Functionality**
PV overvoltage protection is a feature that actively protects the inverter against overvoltage. The function is independent of grid connection and remains active as long as the inverter is fully functional.
During normal operation the MPP voltage will be in the 220–800 V range and the PV overvoltage protection remains inactive. If the inverter is disconnected from grid the PV voltage will be in an open-circuit scenario (no MPP tracking). Under these conditions and with high irradiation and low-module temperature, the voltage may rise and exceed 900 V, potentially stressing the inverter. At this point, overvoltage protection activates.
When the PV overvoltage protection activates, the input voltage is virtually short-circuited, and forced to reduce to approximately 5 V. Just enough power remains to supply the internal circuits. The input voltage reduction is performed within 1.0 ms.
When the normal grid condition is re-established, the inverter will exit the PV overvoltage protection, returning MPP voltage to a level in the 220-800 V range.

**Intermediate Overvoltage Protection**
During start-up (before the inverter is connected to grid) and while PV is charging the intermediate circuit, the overvoltage protection may be activated to prevent overvoltage in the intermediate circuit.

### 3.2.5 Thermal Management

All power electronics units generate excess heat, which must be controlled and removed to avoid damage and to achieve high reliability and long life. The temperature around critical components like the integrated power modules is continuously measured to protect the electronics against overheating. If the temperature exceeds the limits, the inverter reduces input power to maintain temperature at a safe level.
The thermal management concept of the inverter is based on forced cooling with speed-controlled fans. The fans are electronically controlled and are only active when needed.
The rear of the inverter is designed as a heat sink that removes the heat generated by the power semiconductors in the integrated power modules. Additionally, the magnetic parts are ventilated by force.
At high altitudes, the cooling capacity of the air is reduced. The fan control attempts to compensate for this reduced cooling. At altitudes greater than 1000 m, consider derating of the inverter power when planning system layout, to avoid loss of energy.

| Altitude | **2000 m** |
|---|---|
| Max. load of inverter | 95% |

**Table 3.4 Compensation for Altitude**

***NOTICE***

**PELV protection is effective up to 2000 m above sea level only.**

Account for other altitude-related factors, such as increased irradiation.

Optimise reliability and lifetime by mounting the inverter in a location with low ambient temperature.

***NOTICE***

**For calculation of ventilation, use maximum heat dissipation of 600 W per inverter.**

### 3.2.6 Simulation of PV

Contact the supplier before connecting the inverter to a power supply for testing purposes, e.g. simulation of PV. The inverter has built-in functionalities that may harm the power supply.

## 3.3 AC Side

### 3.3.1 Requirements for AC Connection

**⚠CAUTION**

**Always follow local rules and regulations.**

The inverters are designed with a 3-phased, neutral and protective earth AC grid interface for operation under the following conditions:

| Parameter | Nominal | Min. | Max. |
|---|---|---|---|
| Grid voltage, phase – neutral | 230 V +/- 20% | 184 V | 276 V |
| Grid frequency | 50 Hz +/- 10% | 45 Hz | 55 Hz |

**Table 3.5 AC Operating Conditions**

When choosing grid code, the parameters in the above specification will be limited to comply with the specific grid codes.

**Earthing systems**

The inverters can operate on TN-S, TN-C, TN-C-S and TT systems.

3

***NOTICE***

**Where an external RCD is required in addition to the built-in RCMU, a 300 mA RCD type B must be used to avoid tripping. IT systems are not supported.**

***NOTICE***

**When using TN-C earthing to avoid earth currents in the communication cable, ensure identical earthing potential of all inverters.**

## 3.3.2 Dimensioning of External Circuits

No consumer load should be applied between the mains circuit breaker and the inverter. An overload of the cable may not be recognised by the cable fuse, see *2.3.1 Functional Overview*. Always use separate fuses for consumer loads. Use dedicated circuit breakers with load switch functionality for load switching. Threaded fuse elements like 'Diazed' and 'Neozed' are not considered adequate as a load switch. Fuse holder may be damaged if dismounted under load. Use the PV load switch to turn off the inverter before removing/replacing the fuse elements. The selection of the mains circuit breaker rating depends on the wiring design (wire cross-sectional area), cable type, wiring method, ambient temperature, inverter current rating etc. Derating of the circuit breaker rating may occur due to self-heating or if exposed to heat.
For mains circuit specifications see *5.5 Mains Circuit Specifications*.
For information about cable requirements see *5.6 Cable Specifications*.

## 3.3.3 Grid Impedance

The grid impedance must correspond to the specifications to avoid unintended disconnection from the grid or derating of the output power. Ensure that cable dimensions are correct, to avoid losses. Allow for the no-load voltage at the connection point.

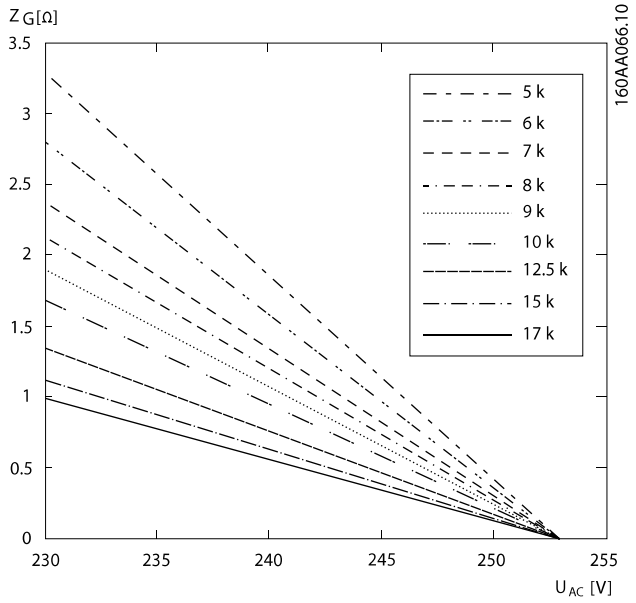



**Illustration 3.11 Maximum Permitted Grid Impedance, as Function of No-load Voltage**

# 4 Options and Communication Interfaces

## 4.1 Introduction

This chapter describes the communication interfaces and option modules available for the inverter.



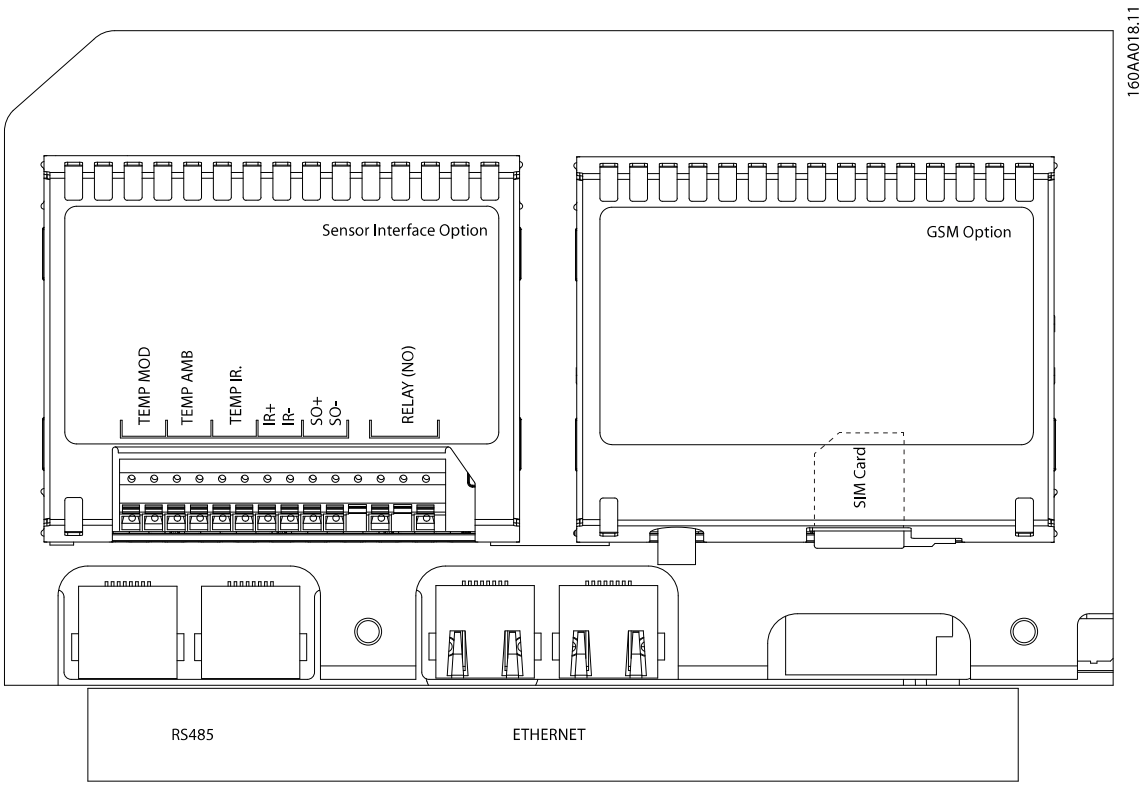



**Illustration 4.1 Location of Sensor Interface Options and Connections on Inverter Comboard**

***NOTICE***

**Sensor interface option/GSM option can be placed left or right.**

For information on installation and detailed specification of option modules refer also to:

- *GSM Option Installation Guide*
- *Sensor Interface Option Installation Guide*

## 4.2 Sensor Interface Option

For information regarding installation, setup, and specifications, refer to the *Sensor Interface Option Installation Guide*.
The sensor interface option provides interfaces for temperature sensor, irradiation sensor, energy meter input and a relay output.

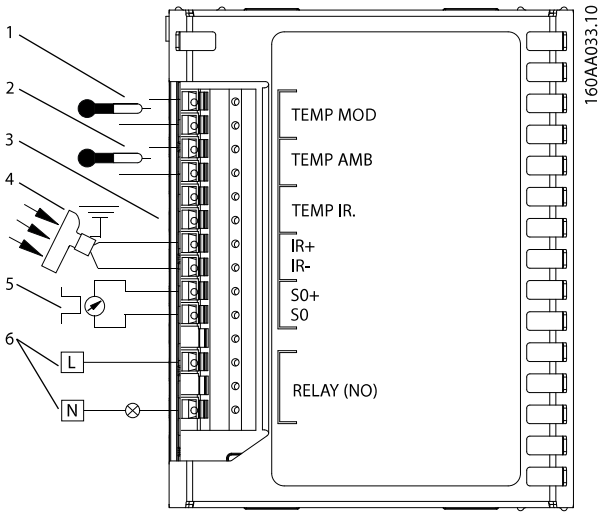



**Illustration 4.2 Sensor Connections to Sensor Interface Option**

| | |
|---|---|
| 1-3 | Interfaces for temperature sensor |
| 4 | Irradiation sensor |
| 5 | Energy meter input (S0) |
| 6 | Relay output |

### 4.2.1 Temperature Sensor

3 inputs for temperature sensors are provided.

| Temperature Sensor Input | Function |
|---|---|
| Ambient temperature | Readout via display or web interface and/or communication (logging) |
| PV module temperature | Readout via display or web interface and/or communication (logging) |
| Irradiation sensor temperature | Internal use for temperature correction of irradiation measurement |

**Table 4.1 Temperature Sensor Inputs**

The supported temperature sensor type is PT1000.

### 4.2.2 Irradiation Sensor

The irradiation measurement is read out via the display or web interface and/or communication (logging). The supported irradiation sensor type is passive with a max. output voltage of 150 mV.

### 4.2.3 Energy Meter Sensor (S0)

The energy meter input is read out via the display or via the web interface and communication (logging). The supported energy meter is supported according to EN62053-31 Annex D. S0 is a logical count input.
Energy meters with 1000 or 5000 pulses per kWh and with a minimum pulse width of 100 ms are supported.

### 4.2.4 Relay Output

The relay output can be used for either of the following purposes:

- as trigger for an alarm or,
- as trigger for self-consumption.

The relay is potential free Type NO (Normally Open).

### 4.2.5 Alarm

The relay can trigger a visual alarm and/or an audible alarm device to indicate events of various inverters (to see which ones, refer to the *FLX User Guide*).

### 4.2.6 Self-consumption

Based on a configurable amount of inverter output power or time of day, the relay can be set to trigger a consumption load (eg. washing machine, heater, etc.).
Once triggered, the relay remains closed until the inverter disconnects from grid (eg. at the end of the day), unless a turn-off time is defined.
To avoid overloading the internal relay, it must be ensured that the external load does not exceed the capability of the internal relay (refer to *Sensor Interface Option Installation Guide*). For loads exceeding the internal relay capability, an auxiliary contactor must be used.

## 4.3 GSM Option Kit

With the GSM option kit the FLX inverter can upload to a data warehouse via FTP and GPRS connection.

Items supplied: GSM option (1), antenna cable (2), and antenna (3), see *Illustration 4.3*.
Additional requirement: Active SIM card with PIN code

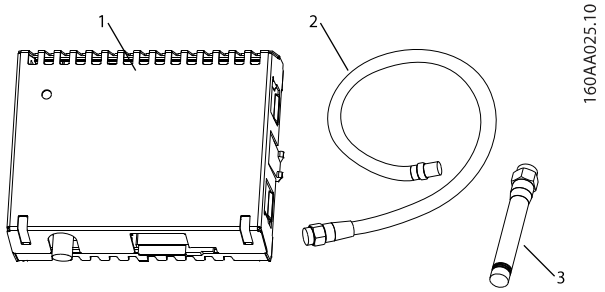



**Illustration 4.3 Items Supplied - GSM Option Kit**

For information regarding installation and setup, refer to the *GSM Option Kit Installation Guide*.

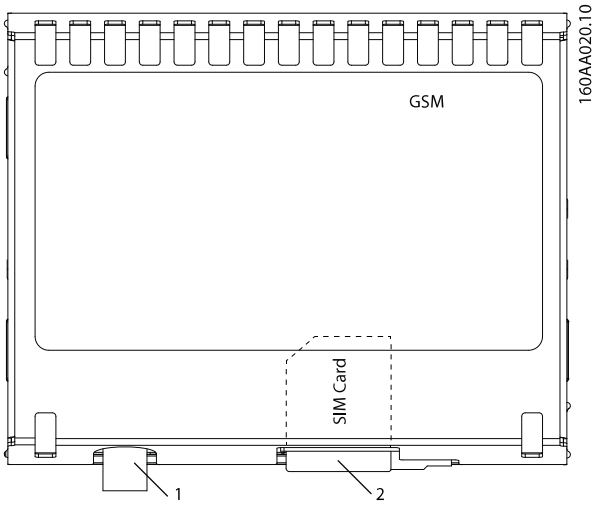



**Illustration 4.4 GSM Option**

| | |
|---|---|
| 1 | Antenna cable connection point |
| 2 | SIM card slot |

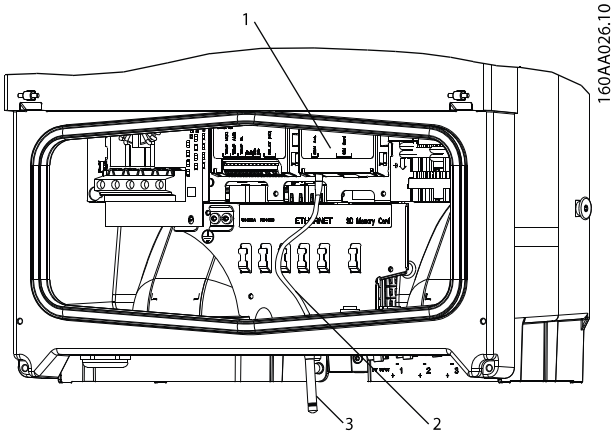



**Illustration 4.5 Correctly Mounted GSM Option with Antenna**

| | |
|---|---|
| 1 | GSM option |
| 2 | Antenna cable |
| 3 | Antenna |

## 4.4 RS-485 Communication

RS-485 communication supports the following Danfoss peripheral units:

- CLX Home
- CLX Standard
- CLX Weblogger
- CLX Home GM
- CLX Standard GM

RS-485 also supports 3rd-party loggers. Contact 3rd-party supplier for compatibility.

For further information on wiring, see *5.9 Auxiliary Interface Specifications*.

Do not connect the RS-485 based communication devices to the inverter, when it is configured as master.

RS-485 communication is used for communication with accessories and for service purposes.

## 4.5 Ethernet Communication

The Ethernet communication is used when applying the master inverter functionality via the web interface.

For layout of the Ethernet interface, see *5.9 Auxiliary Interface Specifications* and *5.10.1 Network Topology*.

For service purposes, Ethernet communication can be used to access the service web interface.

# 5 Technical Data

## 5.1 Technical Data

### 5.1.1 Inverter Specifications

| Nomen-clature | Parameter | FLX series | | | | |
|---|---|---|---|---|---|---|
| | | 5 | 6 | 7 | 8 | 9 |
| | **AC** | | | | | |
| \|S\| | Rated apparent power | 5 kVA | 6 kVA | 7 kVA | 8 kVA | 9 kVA |
| $P_{ac,r}$ | Rated active power[1)] | 5 kW | 6 kW | 7 kW | 8 kW | 9 kW |
| | Active power at cos(phi)=0.95 | 4.75 kW | 5.7 kW | 6.65 kW | 7.6 kW | 8.55 kW |
| | Active power at cos(phi)=0.90 | 4.5 kW | 5.4 kW | 6.3 kW | 7.2 kW | 8.1 kW |
| | Reactive power range | 0 - 3.0 kVAr | 0 - 3.6 kVAr | 0 - 4.2 kVAr | 0 - 4.8 kVAr | 0 - 5.4 kVAr |
| $V_{ac,r}$ | Nominal AC voltage (AC voltage range) | 3P+N+PE - 230/400 V (+/- 20 %) | | | | |
| | Rated current AC | 3 x 7.2 A | 3 x 8.7 A | 3 x 10.1 A | 3 x 11.6 A | 3 x 13 A |
| $I_{acmax}$ | Max. current AC | 3 x 7.5 A | 3 x 9.0 A | 3 x 10.6 A | 3 x 12.1 A | 3 x 13.6 A |
| | AC current distortion (THD at nominal output power, %) | - | - | - | - | - |
| | Inrush current | 9.5 A / 10 ms | | | | |
| $cosphi_{ac,r}$ | Power factor at 100% load | >0.99 | | | | |
| | Controlled power factor range | 0.8 over-excited<br>0.8 under-excited | | | | |
| | Standby consumption | 2.7 W | | | | |
| $f_r$ | Nominal grid frequency (range) | 50 (±5 Hz) | | | | |
| | **DC** | | | | | |
| | Max. PV input power per MPPT | 5.2 kW | 6.2 kW | 7.2 kW | 8 kW | |
| | Nominal power DC | 5.2 kW | 6.2 kW | 7.2 kW | 8.3 kW | 9.3 kW |
| $V_{dc,r}$ | Nominal voltage DC | 715 V | | | | |
| $V_{dcmin}$/ $V_{mppmin}$ - $V_{mppmax}$ | MPP voltage - active tracking [2)] / rated power[3)] | 220/250 - 800 V | 220/260 - 800 V | 220/300 - 800 V | 220/345-800 V | 220/390 - 800 V |
| | MPP efficiency, static | 99.9% | | | | |
| | MPP efficiency, dynamic | 99.7% | | | | |
| $V_{dcmax}$ | Max. DC voltage | 1000 V | | | | |
| $V_{dcstart}$ | Turn on voltage DC | 250 V | | | | |
| $V_{dcmin}$ | Turn off voltage DC | 220 V | | | | |
| $I_{dcmax}$ | Max. MPP current | 12 A per PV input | | | | |

| Nomen-clature | Parameter | FLX series | | | | |
|---|---|---|---|---|---|---|
| | | 5 | 6 | 7 | 8 | 9 |
| | Max. short-circuit current DC (at STC) | 13.5 A per PV input | | | | |
| | Min. on grid power | 20 W | | | | |
| | **Efficiency** | | | | | |
| | Max. efficiency | - | 97.8% | - | 97.9% | - |
| | Euro efficiency, V at $_{dc,r}$ | - | 96.5% | - | 97.0% | - |
| | **Other** | | | | | |
| | Dimensions (H, W, D), inverter / incl. packaging | 667 x 500 x 233 mm / 774 x 570 x 356 mm | | | | |
| | Mounting recommendation | Mounting plate | | | | |
| | Weight, inverter / incl. packaging | 38 kg / 44 kg | | | | |
| | Acoustic noise level[4] | - | | | | |
| | MPP trackers | 2 | | | | |
| | Operation temperature range | -25..60 °C | | | | |
| | Nom. temperature range | -25..45 °C | | | | |
| | Storage temperature | -25..60 °C | | | | |
| | Overload operation | Change of operating point | | | | |
| | Overvoltage categories | Grid: OVC III<br>PV: OVC II | | | | |

**Table 5.1 Specifications**

*[1] At rated grid voltage ($V_{ac,r}$), Cos(phi)=1.*

*[2] To utilise the full range, asymmetrical layouts must be considered including start-up voltage for at least 1 string. Achieving nominal power will depend on configuration.*

*[3] At symmetric input configuration.*

*[4] SPL (Sound Pressure Level) at 1 m under normal operating conditions. Measured at 25 °C.*

| Nomen-clature | Parameter | FLX series | | | | |
|---|---|---|---|---|---|---|
| | | 10 | 12.5 | 15 | 17 | |
| | **AC** | | | | | |
| \|S\| | Rated apparent power | 10 kVA | 12.5 kVA | 15 kVA | 17 kVA | |
| $P_{ac,r}$ | Rated active power[1] | 10 kW | 12.5 kW | 15 kW | 17k W | |
| | Active power at cos(phi)=0.95 | 9.5 kW | 11.9 kW | 14.3 kW | 16.2 kW | |
| | Active power at cos(phi)=0.90 | 9.0 kW | 11.3 kW | 13.5 kW | 15.3 kW | |
| | Reactive power range | 0 - 6.0 kVAr | 0-7.5 kVAr | 0-9.0 kVAr | 0-10.2 kVAr | |
| $V_{ac,r}$ | Nominal AC voltage (AC voltage range) | 3P+N+PE - 230/400 V (+/- 20 %) | | | | |
| | Rated current AC | 3 x 14.5 A | 3 x 18.2 A | 3 x 21.7 A | 3 x 24.7 A | |

5

| Nomen-clature | Parameter | FLX series | | | | |
|---|---|---|---|---|---|---|
| | | 10 | 12.5 | 15 | 17 | |
| $I_{acmax}$ | Max. current AC | 3 x 15.1 A | 3 x 18.8 A | 3 x 22.6 A | 3 x 25.6 A | |
| | AC current distortion (THD at nominal output power, %) | - | <2 % | | | |
| | Inrush current | 0.5 A / 10 ms | | | | |
| $cosphi_{ac,r}$ | Power factor at 100% load | >0.99 | | | | |
| | Controlled power factor range | 0.8 over-excited<br>0.8 under-excited | | | | |
| | Standby consumption | 2.7 W | | | | |
| $f_r$ | Nominal grid frequency (range) | 50 (±5 Hz) | | | | |
| | **DC** | | | | | |
| | Max. PV input power per MPPT | 8 kW | | | | |
| | Nominal power DC | 10.4 kW | 12.9 kW | 15.5 kW | 17.6 kW | |
| $V_{dc,r}$ | Nominal voltage DC | 715 V | | | | |
| $V_{dcmin}$/ $V_{mppmin}$ - $V_{mppmax}$ | MPP voltage - active tracking [2] / rated power[3] | 220/430 - 800 V | 220/360 - 800 V | 220/430 - 800 V | 220/485 - 800 V | |
| | MPP efficiency, static | 99.9% | | | | |
| | MPP efficiency, dynamic | 99.7% | | | | |
| $V_{dcmax}$ | Max. DC voltage | 1000 V | | | | |
| $V_{dcstart}$ | Turn on voltage DC | 250 V | | | | |
| $V_{dcmin}$ | Turn off voltage DC | 220 V | | | | |
| $I_{dcmax}$ | Max. MPP current | 12 A per PV input | | | | |
| | Max. short-circuit current DC (at STC) | 13.5 A per PV input | | | | |
| | Min. on grid power | 20 W | | | | |
| | **Efficiency** | | | | | |
| | Max. efficiency | 98% | | | | |
| | Euro efficiency, V at $_{dc,r}$ | 97.0% | 97.3% | 97.4% | 97.4% | |
| | **Other** | | | | | |
| | Dimensions (H, W, D), inverter / incl. packaging | 667 x 500 x 233 mm / 774 x 570 x 356 mm | | | | |
| | Mounting recommendation | Mounting plate | | | | |
| | Weight, inverter / incl. packaging | 38 kg / 44 kg | 39 kg / 45 kg | | | |
| | Acoustic noise level[4] | - | 55 dB(A) | | | |
| | MPP trackers | 2 | 3 | | | |
| | Operation temperature range | -25..60 °C | | | | |
| | Nom. temperature range | -25..45 °C | | | | |

| Nomen-clature | Parameter | FLX series | | | | |
|---|---|---|---|---|---|---|
| | | 10 | 12.5 | 15 | 17 | |
| | Storage temperature | -25..60 °C | | | | |
| | Overload operation | Change of operating point | | | | |
| | Overvoltage categories | Grid: OVC III<br>PV: OVC II | | | | |

**Table 5.2 Specifications**

*1) At rated grid voltage ($V_{ac,r}$), Cos(phi)=1.*

*2) To utilise the full range, asymmetrical layouts must be considered including start-up voltage for at least 1 string. Achieving nominal power will depend on configuration.*

*3) At symmetric input configuration.*

*4) SPL (Sound Pressure Level) at 1 m under normal operating conditions. Measured at 25 °C.*



| Parameter | FLX series |
|---|---|
| Connector type | Sunclix |
| Parallel mode | Yes |
| Interface | Ethernet (Web interface), RS-485 |
| Options | GSM Option Kit, Sensor Interface Option, PLA Option |
| PV Sweep | Yes |
| Overload operation | Change of operating point |
| Grid supportive functionality | Fault ride through |
| Active power control[5)] | Integrated, or via external device |
| Reactive power control[5)] | Yes |
| DC short-circuit protection | Yes |

**Table 5.3 Inverter Features and Functionalities**

*5) Remote control via external device.*

| Parameter | | FLX series |
|---|---|---|
| **Electrical** | | |
| | Safety (protective class) | Class I (grounded) |
| | PELV on the communi-cation and control card | Class II |
| | Overvoltage categories | Grid: OVC III<br>PV: OVC II |
| **Functional** | | |
| | Islanding detection - loss of mains | • Disconnection<br>• 3-phase monitoring<br>• ROCOF<br>• Active frequency shift |
| | Voltage magnitude | Disconnection, included |
| | Frequency | Disconnection, included |
| | DC content of AC current | Disconnection, included |
| | Insulation resistance | Connection prevented, included |
| | RCMU - Type B | Disconnection, included |

**Table 5.4 Safety Specifications**

### 5.1.2 Efficiency

The efficiency has been measured with a power analyser over a period of 250 s, at 25 °C and 230 V AC grid. The efficiency graphs for the individual types in the FLX series inverter range are depicted below:

Graphs and table pending. Not ready before manual closure.

(Limit = rated value + tolerance).

## 5.2 Derating Limits

To ensure that the inverters can produce the rated power, measurement inaccuracies are taken into account when enforcing the derating limits stated in *Table 5.5*.

5

| | FLX series | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **5** | **6** | **7** | **8** | **9** | **10** | **12.5** | **15** | **17** |
| Grid current, per phase | 7.5 A | 9.0 A | 10.6 A | 12.1 A | 13.6 A | 15.1 A | 18.8 A | 22.6 A | 25.6 A |
| Grid power, total | 5150 W | 6180 W | 7210 W | 8240 W | 9270 W | 10300 W | 12875 W | 15450 W | 17510 W |

**Table 5.5 Derating Limits**

## 5.3 Norms and Standards

| | FLX series | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **International Standards** | **5** | **6** | **7** | **8** | **9** | **10** | **12.5** | **15** | **17** |
| Directive LVD | 2006/95/EC | | | | | | | | |
| Directive EMC | 2004/108/EC | | | | | | | | |
| Safety | IEC 62109-1/IEC 62109-2 | | | | | | | | |
| Integrated PV load switch | VDE 0100-712 | | | | | | | | |
| Functional Safety | IEC 62109-2 | | | | | | | | |
| EMC immunity | EN 61000-6-1 | | | | | | | | |
| | EN 61000-6-2 | | | | | | | | |
| EMC emission | EN 61000-6-3 | | | | | | | | |
| | EN 61000-6-4 | | | | | | | | |
| Utility interference | EN 61000-3-2/-3 | | | | | | EN 61000-3-11/-12 | | |
| CE | Yes | | | | | | | | |
| Utility characteristics | IEC 61727 | | | | | | | | |
| | EN 50160 | | | | | | | | |
| S0 Energy Meter (option) | EN62053-31 Annex D | | | | | | | | |

**Table 5.6 International Standards Compliance**

## 5.4 Installation Conditions

| Parameter | Specification |
|---|---|
| Temperature | −25 °C - +60 °C (for temperature derating, see *2.3.5 Derating*.) |
| Relative humidity | 95 % (non-condensing) |
| Pollution degree | PD2 |
| Environmental class according to IEC | IEC60721-3-3<br>3K6/3B3/3S3/3M2 |
| Air quality - general | ISA S71.04-1985<br>Level G2 (at 75% RH) |
| Air quality - coastal, heavy industrial and agricultural zones | Must be measured and classified acc. to ISA S71.04-1985 |
| Vibration | 1G |
| Observe product ingress protection class | IP65 |
| Max. operating altitude | 2000 m above sea level.<br>PELV protection is effective up to 2000 m above sea level only. |
| Installation | Avoid constant stream of water.<br>Avoid direct sunlight.<br>Ensure adequate air flow.<br>Mount on non-flammable surface.<br>Mount upright on vertical surface.<br>Prevent dust and ammonia gases.<br>The FLX inverter is an outdoor unit. |

**Table 5.7 Conditions for Installation**

| Parameter | Condition | Specification |
|---|---|---|
| Mounting plate | Hole diameter | 30 x 9 mm |
| | Alignment | Perpendicular ±5° all angles |

**Table 5.8 Mounting Plate Specifications**

## 5.5 Mains Circuit Specifications

| | FLX series | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 12.5 | 15 | 17 |
| Maximum inverter current, $I_{acmax}$ | 7.5 A | 9 A | 10.6 A | 12.1 A | 13.6 A | 15.1 A | 18.8 A | 22.6 A | 25.6 A |
| Recommended blow fuse type gL/gG*) | 10 A | 13 A | 13 A | 13 A | 16 A | 16 A | 20 A | 25 A | 32 A |
| Recommended automatic fuse type B or C*) | 16 A | 16 A | 16 A | 20 A | 20 A | 20 A | 25 A | 25 A | 32 A |

**Table 5.9 Mains Circuit Specifications**

*) *Always choose fuses according to national regulations.*

## 5.6 Cable Specifications

***NOTICE***

**Avoid power loss in cables greater than 1% of the nominal inverter rating by following the values stated in the tables and illustrations.**

***NOTICE***

**Table states only cable lengths less than 100 m.**

| Specification | | FLX series | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| AC cable maximum length [m] | AC cable size | 5 | 6 | 7 | 8 | 9 | 10 | 12.5 | 15 | 17 |
| | 2.5 $mm^2$ | 43 m | 36 m | 31 m | 27 m | 24 m | 21 m | 1) | 1) | 1) |
| | 4 $mm^2$ | 69 m | 57 m | 49 m | 43 m | 38 m | 34 m | 27 m | 2) | 2) |
| | 6 $mm^2$ | | 86 m | 74 m | 64 m | 57 m | 52 m | 41 m | 34 m | 30 m |
| | 10 $mm^2$ | | | | | 95 m | 86 m | 69 m | 57 m | 51 m |
| | 16 $mm^2$ | | | | | | | | 92 m | 81 m |
| AC cable type | | 5-wire copper cable | | | | | | | | |
| AC cable outer diameter | | 18-25 mm | | | | | | | | |
| AC cable insulation strip | | Strip 16 mm length of insulation from all 5 wires | | | | | | | | |
| PE cable diameter | | Equal to or greater than diameter of AC phase cables | | | | | | | | |

**Table 5.10 AC Cable Specifications**

*1) Using cable with a diameter less than 4 $mm^2$ is not recommended.*

*2) Using cable with a diameter less than 6 $mm^2$ is not recommended.*

| Specification | | FLX series |
|---|---|---|
| DC cable type | | Min. 1000 V, 13.5 A |
| DC cable length | DC cable size 4 $mm^2$ - 4.8 Ω /km | < 200 m* |
| | DC cable size 6 $mm^2$ - 3.4 Ω /km | 200-300 m* |
| Mating connector | | Sunclix PV-CM-S 2,5-6(+) / PV-CM-S 2,5-6(-) |

**Table 5.11 DC Cable Specifications**

** The distance between inverter and PV array and back, plus the cumulative length of the cables used for PV array installation.*

Consider also the following when choosing cable type and cross-sectional area:

- Ambient temperature
- Layout type (inside wall, under ground, free air etc.)
- UV resistance

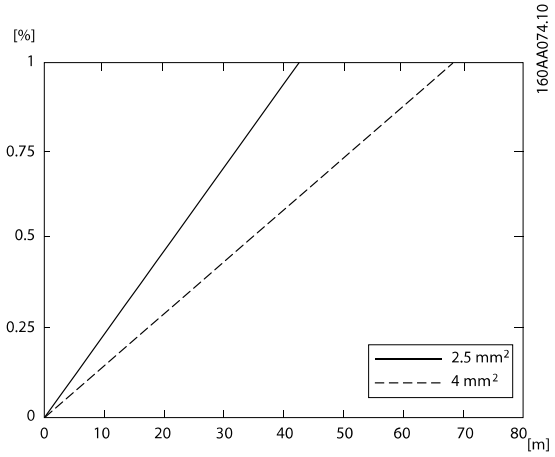



**Illustration 5.1 FLX Series 5, Cable Losses [%] versus Cable Length [m]**

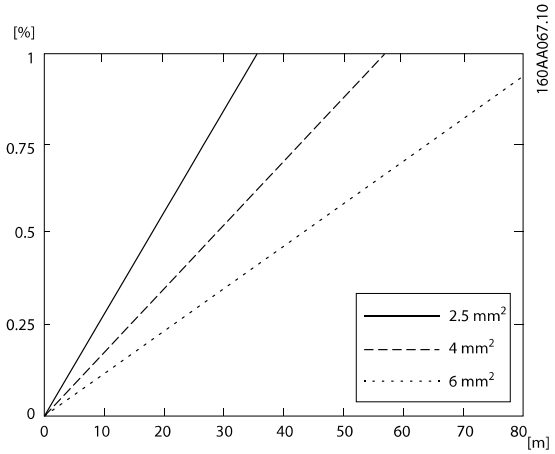



**Illustration 5.2 FLX Series 6, Cable Losses [%] versus Cable Length [m]**

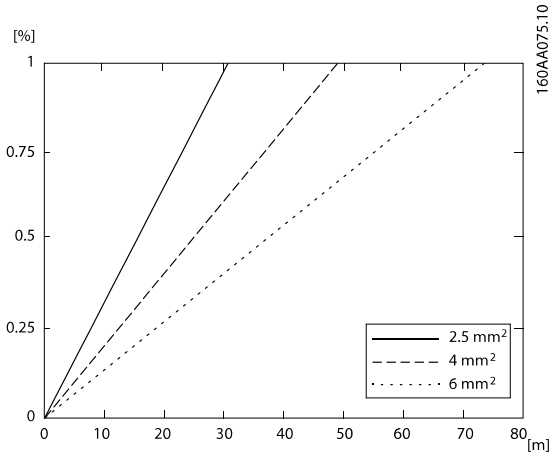



**Illustration 5.3 FLX Series 7, Cable Losses [%] versus Cable Length [m]**

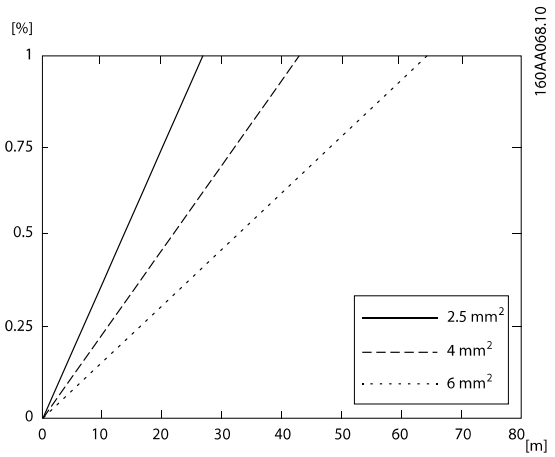



**Illustration 5.4 FLX Series 8, Cable Losses [%] versus Cable Length [m]**

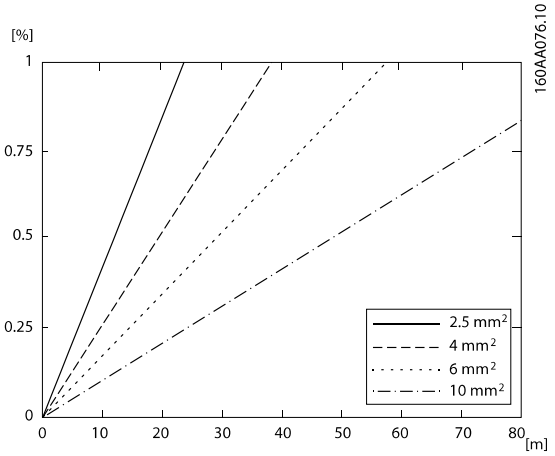



**Illustration 5.5 FLX Series 9, Cable Losses [%] versus Cable Length [m]**

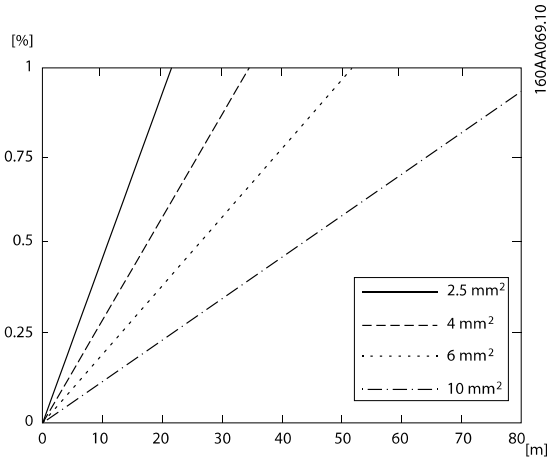



**Illustration 5.6 FLX Series 10, Cable Losses [%] versus Cable Length [m]**

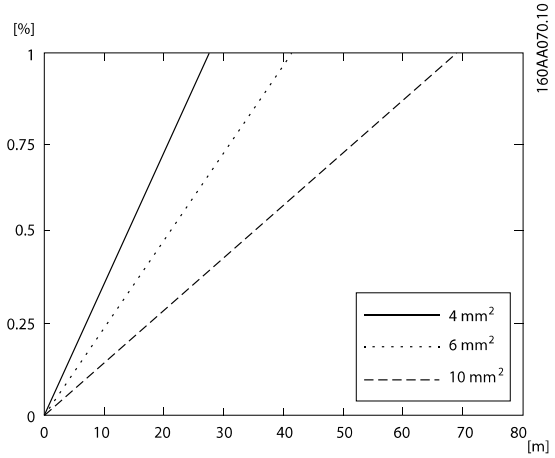



**Illustration 5.7 FLX Series 12.5, Cable Losses [%] versus Cable Length [m]**

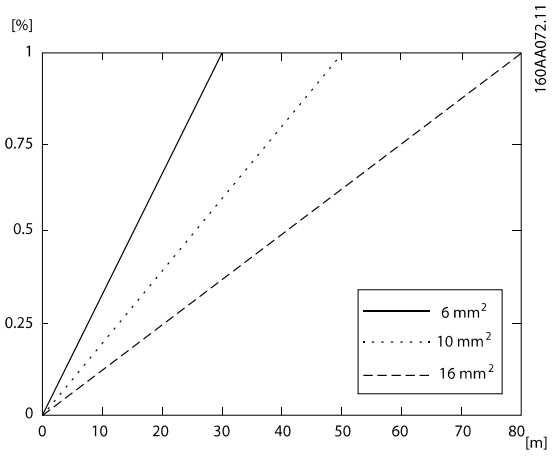



**Illustration 5.9 FLX Series 17, Cable Losses [%] versus Cable Length [m]**

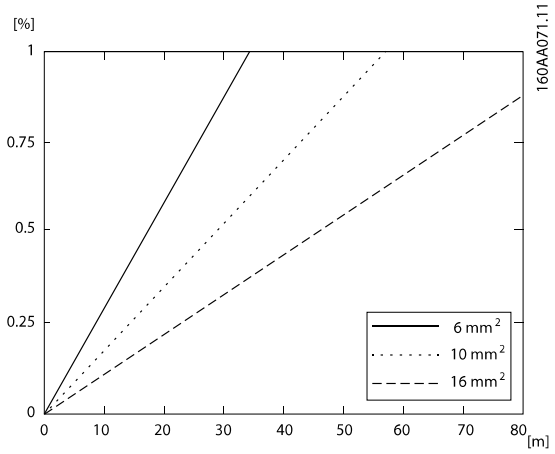



**Illustration 5.8 FLX Series 15, Cable Losses [%] versus Cable Length [m]**

## 5.7 Torque Specifications

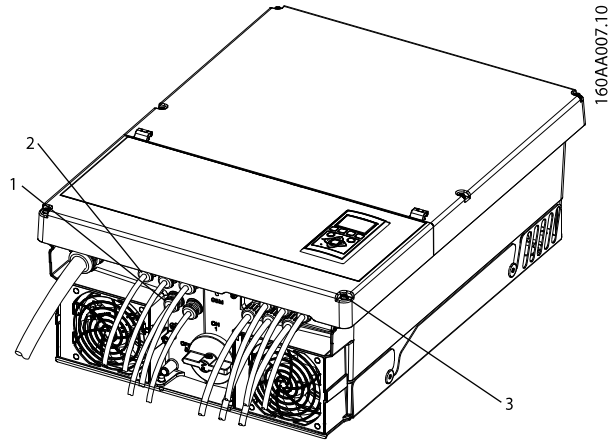



**Illustration 5.10 Overview of Inverter with Torque Indications 1**

| | Parameter | Tool | Tightening Torque |
|---|---|---|---|
| 1 | M16 cable gland body | Wrench 19 mm | 3.75 Nm |
| | M16 cable gland, compression nut | Wrench 19 mm | 2.5 Nm |
| 2 | M25 cable gland body | Wrench 27 mm | 7.5 Nm |
| | M25 cable gland, compression nut | Wrench 27 mm | 5.0 Nm |
| 3 | Front screw | Torx TX 20 | 1.5 Nm |

**Table 5.12 Nm Specifications 1**

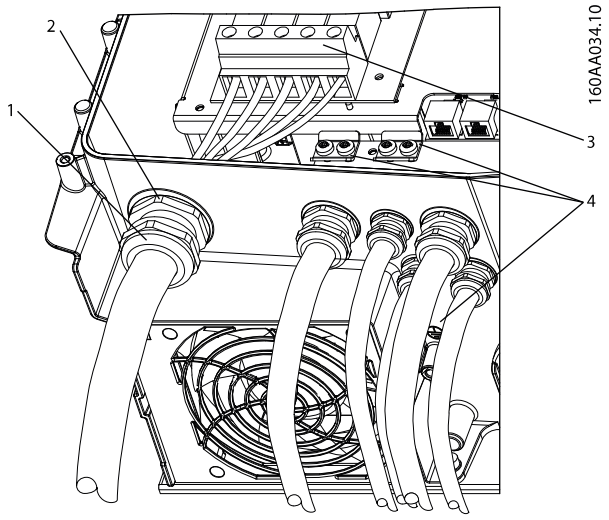



**Illustration 5.11 Overview of Inverter with Torque Indications 2**

| | Parameter | Tool | Tightening Torque |
|---|---|---|---|
| 1 | M32 cable gland body | Wrench 42 mm | 7.5 Nm |
| 2 | M32 cable gland, compression nut | Wrench 42 mm | 5.0 Nm |
| 3 | Terminals on AC terminal block | Pozidriv PZ2 or Straight slot 1.0 x 5.5 mm | 2.0 - 4.0 Nm |
| 4 | PE | Torx TX 20 or Straight slot 1.0 x 5.5 mm | 2.2 Nm |

**Table 5.13 Nm Specifications 2**



## 5.8 Mains Circuit Specifications

| | FLX series | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 12.5 | 15 | 17 |
| Maximum inverter current, $I_{acmax}$ | 7.5 A | 9 A | 10.6 A | 12.1 A | 13.6 A | 15.1 A | 18.8 A | 22.6 A | 25.6 A |
| Recommended blow fuse type gL/gG*) | 10 A | 13 A | 13 A | 13 A | 16 A | 16 A | 20 A | 25 A | 32 A |
| Recommended automatic fuse type B or C*) | 16 A | 16 A | 16 A | 20 A | 20 A | 20 A | 25 A | 25 A | 32 A |

**Table 5.14 Mains Circuit Specifications**

**) Always choose fuses according to national regulations.*

## 5.9 Auxiliary Interface Specifications

| Interface | Parameter | Parameter Details | Specification |
|---|---|---|---|
| RS-485 and Ethernet | Cable | Cable jacket diameter (⌀) | 2x5-7 mm |
| | | Cable type | Shielded Twisted Pair (STP CAT 5e or SFTP CAT 5e) 2) |
| | | Cable characteristic impedance | 100 Ω – 120 Ω |
| | RJ-45 connectors:<br>2pcs RJ-45 for RS-485<br>2pcs RJ-45 for Ethernet | Wire gauge | 24-26 AWG (depending on mating metallic RJ-45 plug) |
| | | Cable shield termination | Via metallic RJ-45 plug |
| | Galvanic interface insulation | | Yes, 500 Vrms |
| | Direct contact protection | Double/Reinforced insulation | Yes |
| | Short-circuit protection | | Yes |
| RS-485 only | Cable | Max. cable length | 1000 m |
| | Max. number of inverter nodes | | 63 |
| Ethernet only | Communication | Network topology | Star and daisy chain |
| | Cable | Max. cable length between inverters | 100 m |
| | Max. number of inverters | | 100 1) |

**Table 5.15 Auxiliary Interface Specifications**

*1) Max. number of inverters are 100. If GSM modem is used for portal upload, the number of inverters in a network is limited to 50.*

*2) For outdoor use, we recommend outdoor burial type cable (if buried in the ground) for both Ethernet and RS-485.*

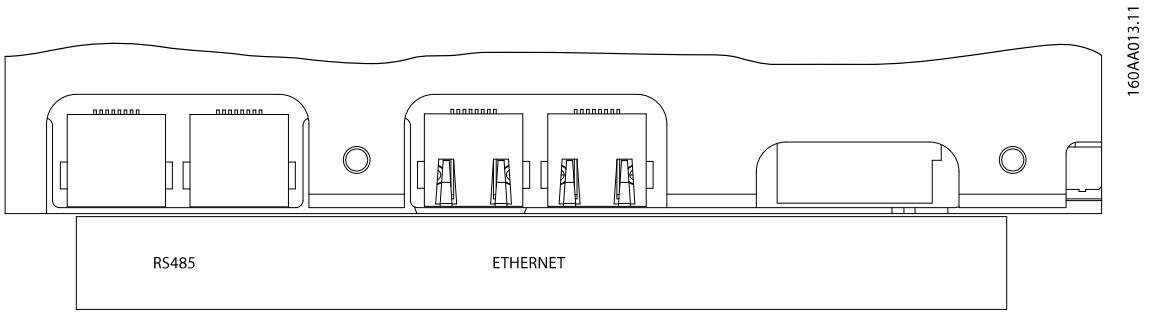



**Illustration 5.12 Auxiliary Interfaces**

5

## 5.10 RS-485 and Ethernet Connections

**RS-485**

Terminate the RS-485 communication bus at both ends.

- Termination is automatic when no RJ-45 plug is inserted into the socket. The absence of a mating connector enables both termination and bias.
- In rare cases, bias is unwanted, but termination is required. To terminate the RS-485 bus, mount a 100 Ω termination resistor between pin 3 and 6 of an RJ-45 field mountable connector. Then insert the connector (with resistor) into the unused RJ-45 connector.

The RS-485 address of the inverter is unique, and defined at the factory.

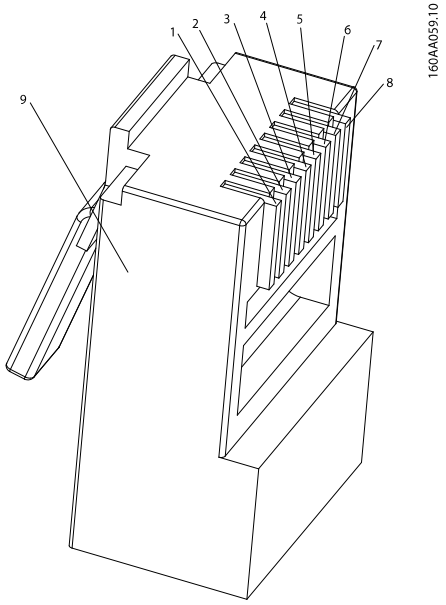



**Illustration 5.13 RJ-45 Pinout Detail for RS-485**

| | |
|---|---|
| 1. | **GND** |
| 2. | GND |
| 3. | **RX/TX A** (-) |
| 4. | BIAS L |
| 5. | BIAS H |
| 6. | **RX/TX B** (+) |
| 7. | Not connected |
| 8. | Not connected |
| 9. | **Screen** |

***Bold*** *= Compulsory, Cat5 cable contains all 8 wires.*
*For Ethernet: 10Base-TX and 100Base-TX auto cross-over.*

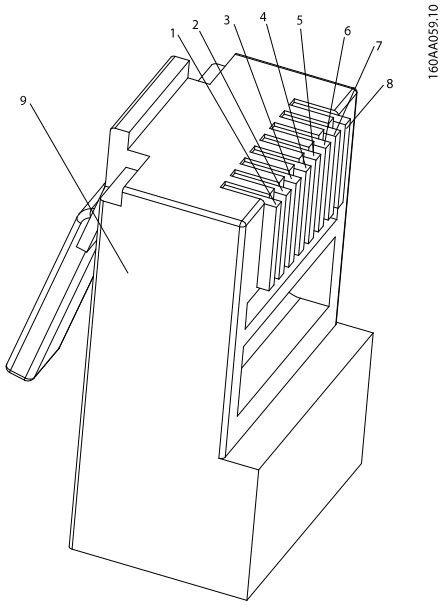



**Illustration 5.14 RJ-45 Pinout Detail for RS-485**

| Pinout Ethernet | Colour Standard | |
|---|---|---|
| | **Cat 5 T-568A** | **Cat 5 T-568B** |
| 1. RX+ | Green/white | Orange/white |
| 2. RX | Green | Orange |
| 3. TX+ | Orange/white | Green/white |
| 4. | Blue | Blue |
| 5. | Blue/white | Blue/white |
| 6. TX- | Orange | Green |
| 7. | Brown/white | Brown/white |
| 8. | Brown | Brown |
| 9. | Screen | Screen |

## 5.10.1 Network Topology

The inverter has 2 Ethernet RJ-45 connectors enabling the connection of several inverters in a line topology as an alternative to the typical star topology. The 2 ports are similar and may be used interchangeably. For RS-485, only linear daisy chain connections can be used.

***NOTICE***

**Ring topology is not permitted.**

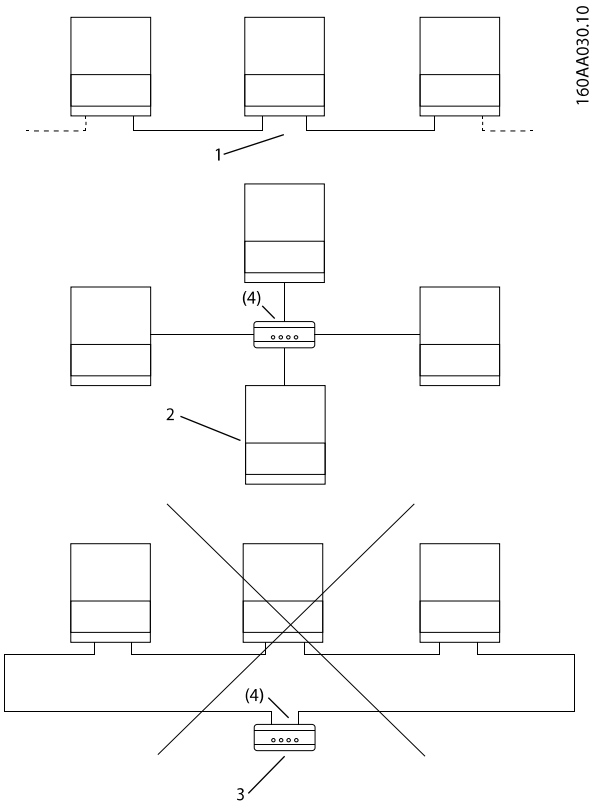



**Illustration 5.15 Network Topology**

| | |
|---|---|
| 1 | Linear Daisy Chain |
| 2 | Star Topology |
| 3 | Ring Topology (not permitted) |
| (4) | (Ethernet Switch) |

***NOTICE***

**The 2 network types cannot be mixed. The inverters can only be connected in networks which are either solely RS-485 or solely Ethernet.**

***NOTICE***

**Ethernet is recommended for faster communication. RS-485 is required when a weblogger or datalogger is connected to the inverter.**

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